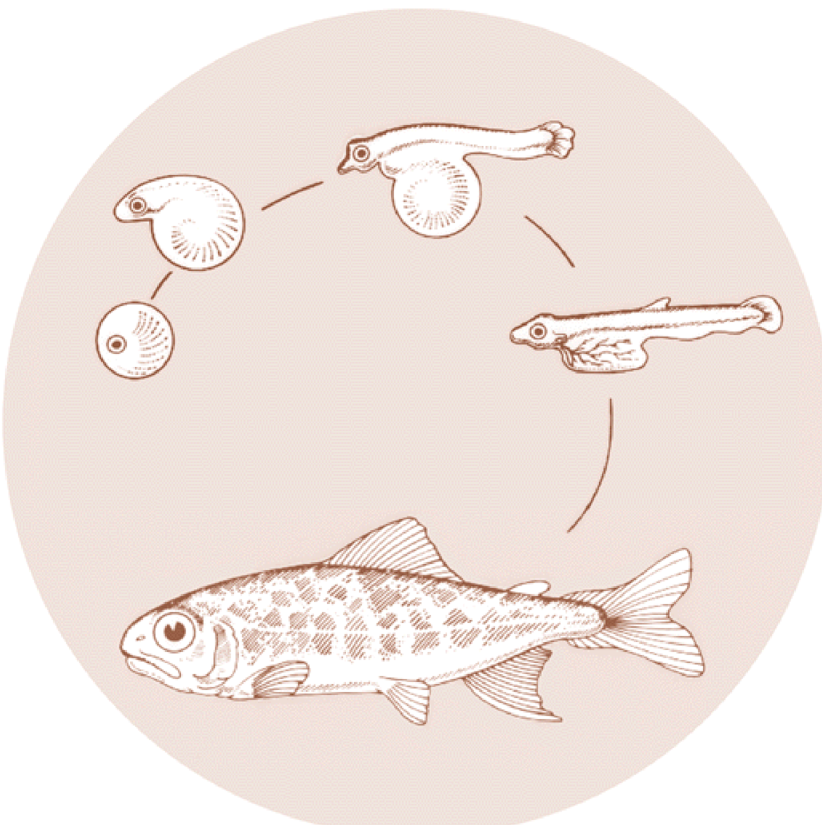
March 1994

EVALUATION OF JUVENILE FISH BYPASS AND ADULT FISH PASSAGE FACILITIES AT WATER DIVERSIONS IN THE UMATILLA RIVER

Annual Report 1993



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EVALUATION OF JUVENILE FISH BYPASS AND ADULT FISH PASSAGE FACILITIES AT WATER DIVERSIONS IN THE UMATILLA RIVER

Annual Report 1993

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CONTENTS

EXECUTIVE SUMMARY

We report on our progress from October 1992 through September 1993 in evaluating juvenile fish bypass facilities at Three Mile Falls, Maxwell, Westland, and Feed Canal dams on the Umatilla River, and in evaluating adult fish passage in the lower Umatilla River. The study is a cooperative effort by the Oregon Department of Fish and Wildlife (ODFW) and the Confederated Tribes of the Umatilla Indian Reservation (CTUIR). We also report on ODFW's effort in May 1992 to evaluate delayed mortality and stress responses of juvenile salmonids resulting from trapping and transport at high temperatures. These are the study objectives addressed:

1. Report A (ODFW): To evaluate the juvenile fish bypass facility and juvenile fish trapping and loading procedures at Westland Canal. To evaluate fish injury incurred during passage through the east-bank ladder at Three Mile Falls Dam and headworks canal at Maxwell Dam. To evaluate fry impingement on secondary screens at the West Extension Irrigation District (WEID) Canal. To measure water velocities at screening structures at Westland, Maxwell, and Feed canals.

2. Report B (CTUIR): To examine the passage of adult salmonids past diversions in the lower Umatilla River using radio telemetry, and determine homing needs.

3. Report C (ODFW): To determine the delayed mortality of salmonids and evaluate the response of salmonids to secondary stressors after being trapped at Westland Canal, transported at various densities, and released in the lower Umatilla River at high temperatures.

These studies are part of a program to rehabilitate anadromous fish stocks in the Umatilla River Basin, including restoration of coho salmon (*Oncorhynchus kisutch*) and chinook salmon (*Oncorhynchus tshawytscha*), as well as enhancement of summer steelhead (*Oncorhynchus mykiss*).

Report A

Our evaluation of (1) the juvenile fish bypass facility and trap and haul procedures at Westland Canal, (2) evaluation of juvenile fish injury at the east-bank adult fish ladder at Three Mile Falls Dam and in the canal approach to Maxwell Canal, (3) evaluation of fish impingement on the secondary screen at WEID Canal, and (4) measurement of water velocities at screening structures in Maxwell, Westland, and Feed canals produced the following highlights:

1. Mean, net weighted injury rates were low for juvenile spring and fall chinook salmon moving through the headgates and upper and lower bypass at Westland Canal. The difference between treatment and control group injury rates did not exceed 1.7% and was not significant.

2. Injury to river-run juvenile salmonids occurred with crowding and dip-netting of fish prior to transport from the Westland facility. Dip-netting imparted more injury to fish than crowding in the holding pond.

3. Most juvenile salmon released upstream from the headgates were not diverted into the canal. Mean diversion rates were 28.2% for fall chinook salmon and 0.2% for spring chinook salmon.

4. Fifty percent of the spring and fall chinook salmon released downstream of the headgates at Westland Canal were recaptured at the bypass downwell in less than 3 hours. Ninety-five percent recovery averaged 7.8 hours for fall chinook salmon and 16.0 hours for spring chinook salmon. The difference between chinook salmon recapture rates was not significant.

5. Only about one-third of the spring chinook salmon released in the bypass downwell at Westland Canal were recaptured at the bypass outlet. Most of these fish were collected within one-half hour after release.

6. The efficiency of the 10 drum-screens at Westland Canal in oreventina frv leakage into the canal ranged from 99.81% to 100%. The small degree of fry leakage primarily occurred at the two end screens. Mean fork length of fry caught behind the screens was 53.5 mm. Fifteen moribund or dead subyearling salmon were also captured behind Drum Screens 1, 7, 8, 9, and 10 during four days in June.

7. Approach velocities at the Westland Canal drum screens were generally within criteria, but were not uniform; highest approach velocities occurred at 80% of water depth and at screens located near the bypass channel entrance. Sweep velocities were lowest at 80% water depth at all screens and highest at shallower'depths at Screens 5 through 10.

8. The two traveling screens at Westland Canal were 100% efficient in preventing fry leakage into the pumpback bay. Approach and sweep velocities at the screens were generally within criteria; the upstream transect of Screen 1 usually had the highest approach velocities.

9. Water velocity and flow at the bypass channel entrance at Westland Canal increased from 3.22 feet per second (fps) and 18 cubic feet per second (cfs) with the weir gate 30% raised, to 3.74 fps and > 23 cfs with the weir gate full down.

10. Subyearling fall chinook salmon received significant injury passing through the east-bank ladder at Three Mile Falls Dam; spring chinook salmon did not, but results were inconclusive. Most injury was inflicted on fish passing through the upper diffuser gratings on the passage side of the ladder and not through the auxiliary water side.

11. Some impingement of fry (< 1%) on the traveling screen at the West Extension Irrigation District Canal occurred when the river-return drain pipe was 40% open and when both canal pumps were operated. Impingement occurred along the downstream edge of the traveling screen, and at times fry were caught between the screen and the side seal.

12. Subyearling fall chinook salmon traveled the 1.5-mile canal headworks at Maxwell Dam an average of 2.9 hours (median travel time) and received few injuries during passage. Fish traveled slower and were recovered less during the day than at evening or night.

13. Approach velocities at the Maxwell Canal drum screens were within criteria for salmonid fingerlings, but usually not for salmonid fry. Approach velocities were not uniform throughout the water column or between screens. Sweep velocities were highest at the screen near the bypass channel entrance; channel velocities averaged 2.34 fps.

14. Approach velocities at the Feed Canal drum screens exceeded criteria for salmonid fry and fingerlings in 80% and 42% of the sampling locations, respectively, when the canal headworks elevation was 1.5 feet below normal operation criteria. Approach velocities were highest at 60% of water depth, at upstream transects on all screens, and at screens closest to the bypass channel entrance. Sweep velocities exceeded 1.0 fps in most locations except Screen 1 where mean sweep velocity was 0.27 fps. Mean approach velocity at the bypass channel entrance was 3.02 fps.

15. To recollect fish during tests at Westland Canal, we designed 10 pairs of fyke nets and frames for the drum screens, an inclined plane trap for the bypass downwell, and a floating fyke net for the bypass outlet.

Report B

Our examination of the passage of adult salmonids past diversions in the lower Umatilla River and assessment of homing needs produced the following highlights:

1. The radio telemetry feasibility study, using high frequency (150 MHz) pulse-code transmitters, was successful with summer steelhead and spring chinook salmon. However, the smaller-sized tags inserted in summer steelhead created more regurgitation problems.

2. Of 13 summer steelhead radio-tagged at Three Mile Falls Dam between 15 December 1992 and 12 May 1993, 8 (61%) successfully negotiated the lower 32 miles of the Umatilla River. Migrational behavior was variable with an average of 30 days required to migrate from Three Mile Falls Dam (RKm 6.4) to Stanfield Dam (RKm 52.3).

3. Upstream migration of summer steelhead was slow when water temperatures were < 5.6 C, river flow was high (> 2,000 cfs), and with early entry of fish in the river. Entry timing extended from October to May.

4. Of the 10 spring chinook salmon radio-tagged between 22 April and 19 May 1993, 7 (70%) migrated past the major diversion dams within an average of 11 days. One fish became trapped within Westland Canal and one fish fell back to Three Mile Falls Dam and was subsequently transported.

5. Some spring chinook salmon had difficulty negotiating Feed Canal Dam at river flows < 450 cfs; poor attraction flows within the vicinity of the fish ladder and the inability to jump the dam were delay factors.

6. During a 4-day operation of both fish ladders at Three Mile Falls Dam, 17 summer steelhead (13%) used the west-bank ladder and 113 steelhead (87%) used the east-bank ladder. Fish ascended the west-bank ladder safely and

effectively, but the associated trapping facility has numerous operational problems precluding its use.

7. Homing rates for fall chinook salmon released at age 0^{++} in 1988 after acclimation were improved (50%) over 0^{++} fish directly released (38.5%). From releases made between 1984 and 1987, acclimated 1^{+} fall chinook salmon had a weighted average homing rate of 75% versus 13.7% for acclimated 0^{++} fish.

8. Although fall chinook salmon are within the vicinity of the mouth of the Umatilla River in early September, fish have not entered the river in substantial numbers until mid to late October. Increasing flows and decreasing temperatures may trigger greater upriver movement in October.

9. Coho salmon adults have strayed as much as 25.5%, with a large percentage of these strays returning to their rearing facility. Homing rates for acclimated versus direct release coho salmon have been similar, indicating imprinting may occur prior to Umatilla River acclimation and release.

10. Six spring chinook salmon radio-tagged at John Day Dam by the University of Idaho, and later trapped at Three Mile Falls Dam, had migrated up to and over McNary Dam prior to falling back and entering the Umatilla River, despite strong attraction flows.

Report C

Our determination of the delayed mortality of juvenile salmonids and evaluation of the response of salmonids to secondary stressors after being trapped at Westland Canal, transported at various densities, and released in the lower Umatilla River at high temperatures produced the following highlights:

1. Water quality parameters for the high-density transport group at release included low dissolved oxygen (5.4 mg/l), a pH of 6.9, and 2.81 mg/l for total ammonia. Water quality for the low-density transport groups was improved. Dissolved oxygen (9.8 - 12.8 mg/l) and pH (7.2 - 7.3) were higher and total ammonia (0.95 - 1.10 mg/l) was lower. Temperatures were at or near 14.0 C for both density transport groups.

2. Average delayed mortality of chinook salmon held for 48 hours after transport was highest for the low-density transport groups (0.77%) and less for the high-density transport groups (0.32%) and control groups (0%). Average wound rate was significantly greater for the low-density transport groups (1.25%) than the high-density transport groups (0.07%) or control groups (0.16%).

3. The low-density transport groups suffered significantly greater mortality (68.18%) after being subjected to secondary stressors than the high density transport groups (34.78%) or the control groups (6.81%).

4. The loading process appears to be the primary factor causing stress and injury to fish. Low-density transport groups were subjected to additional and prolonged crowding during the loading process.

REPORT A

Evaluation of juvenile salmonid bypass facilities, passage, and trapping and loading procedures at various water diversions in the lower Umatilla River and development of trap designs

Prepared By:
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CONTENTS (continued)

ABSTRACT

We report on our efforts from October 1992 through September 1993 to evaluate juvenile salmonid passage through the Westland Canal fish bypass facility on the Umatilla River. Passage success was evaluated by injury and screen leakage tests and estimates of travel time through the facility components. We also report on efforts to (1) evaluate fish injury incurred during juvenile fish trapping and loading procedures at Westland Canal, and during passage through the east-bank ladder at Three Mile Falls Dam and headworks canal at Maxwell Dam; (2) evaluate fish impingement on secondary screens at the West Extension Irrigation District (WEID) Canal; and (3) measure water velocities at screening structures at Westland, Maxwell, and Feed canals.

Facility-caused injury to spring and fall chinook salmon (0. tshawytscha) was low in all tests at Westland Canal. Juvenile fish incurred some injury during dip-netting and crowding prior to transport; dip-netting appeared to cause greater injury than crowding. Diversion rates from releases made above the headgates during moderate to high river flows were low for both the spring chinook (0.2%) and fall chinook salmon (28.2%). Time to recover 50% of spring and fall chinook salmon released downstream of the headgates ranged from 0.2 hours to 3.0 hours. Time to recover 95% of the fall chinook salmon was less (7.8 hours) than for the spring chinook salmon (16.0 hours). Most of the spring chinook salmon released in the lower bypass were not recaptured at the bypass outlet (63.9%).

Drum screens were 99.81% to 100% efficient in preventing fry leakage and traveling screens were 100% efficient. The small degree of fish leakage primarily occurred through the end drum screens. Roll-over of dead or moribund subyearling fall chinook salmon occurred on the drum screens during their outmigration, particularly at Screens 8 and 10. At high canal flow, drum screen approach and sweep velocities were generally within criteria, although velocities were not uniform among screens, screen transects, or water depths. Both velocities increased at screens closest to the bypass channel. Velocities at the traveling screens were also generally within criteria; higher approach velocities were found at the upstream transect of Screen 1. Bypass channel velocity exceeded 3 feet per second with a 30% raised weir; velocity approached 4 feet per second with a fully lowered weir.

Subyearling fall chinook salmon received significant injury passing through the east-bank ladder at Three Mile Falls Dam; spring chinook salmon did not. Injury was incurred primarily through the passage portion of the ladder and not the auxiliary water portion. Some impingement (< 1%) occurred along the downstream edge of the WEID traveling screen when the river-return drain pipe was 40% open or when both canal pumps were on. Subyearling chinook salmon received few injuries traveling through the 1.5-mile canal headworks at Maxwell Dam. Fifty percent of the fish traveled the distance within 3 hours; only 78.8% of the fish were recaptured. Approach and sweep velocities at the drum screens were not uniform among screens and water depth, but were mostly within criteria. Mean velocity at the bypass channel was 2.34 feet per second. Approach velocities at Feed Canal drum screens exceeded criteria for salmonid fry at most locations. Highest approach velocities occured at Screen 10 and at 60% of water depth. Sweep velocities were near 2 feet per second at some screens. Bypass channel velocity was near 3 feet per second.

INTRODUCTION

Large runs of salmon (Oncorhyncos spp.) and steelhead (0. mykiss) once supported productive fisheries in the Umatilla River. By the 1920s, stream impoundments with inadequate passage facilities and habitat degradation had extirpated the salmon run and drastically reduced the steelhead run (ODFW and CTUIR 1989a). However, a comprehensive fisheries rehabilitation program was initiated in the mid-1980s that improved passage facilities, fish habitat, hatchery production, and river flow (Boyce 1986). Improvements in salmon runs in the Umatilla River are presently sufficient to provide a fishery, but still well below long-range production goals (ODFW and CTUIR 1989b).

The Northwest Power Planning Council's Columbia River Basin Fish and Wildlife Program (1987) provided the impetus for fisheries rehabilitation projects throughout the Columbia Basin (Section 1403, Measure 4.2). Reconstruction of ineffective passage facilities on the Umatilla River was a cooperative effort among the Bonneville Power Administration (BPA), Confederated Tribes of the Umatilla Indian Reservation (CTUIR), various fish and wildlife agencies, and the U.S. Bureau of Reclamation (USBR). These improvements included reconstructed or new fish ladders, state-of-the-art bypass facilities, newly designed canal screens, and at some locations, fish trapping and holding facilities.

Evaluation of passage facilities at irrigation diversions on the Umatilla River was recommended in *A Comprehensive Plan for Rehabilitation of Anadromous Fish Stocks in the Umatilla River Basin* (Boyce 1986). We are presently evaluating juvenile fish passage at major irrigation diversions while CTUIR, under subcontract to Oregon Department Fish and Wildlife (ODFW), evaluates adult fish passage at and between these diversions (Report 8). Evaluations of similar fish screening facilities on the Yakima River, Washington, were used as a general model for the juvenile passage study design (Neitzel et al. 1985, 1987, 1988, 1990a, 1990b; and Hosey and Associates 1988a, 1988b, 1989, 1990).

We operated the West Extension Irrigation District (WEID) Canal fish bypass facility in 1989 to test fish sampling equipment. In 1990, 1991: and 1992 we conducted fish injury and leakage tests and collected data on river-run fish (Knapp and Ward 1990, Hayes et al. 1992, Cameron and Knapp 1993) Tests of injury and leakage showed that juvenile salmonids were not injured during passage through the bypass facility and that screening efficiency of the drum screens approached 100%. Impingement of fry and subyearling fish on the traveling screen was the most serious problem observed. We found that fish moved freely through the upper screening facility, but were delayed in the outfall at a bypass flow of 5 cfs. Findings from our evaluation studies have resulted in structural and operational improvements to the facility.

In 1992, we also compared juvenile salmonid passage rates through the WEID Canal fish bypass facility with passage rates through the east-bank fish ladder. Downstream passage rates of juvenile salmonids at the fish ladder was roughly equal to passage rates at the fish bypass facility (Cameron and Knapp 1993). This finding prompted us to broaden the scope of our study to include evaluation of injury to juvenile salmonids incurred during passage through fish ladders.

In this report we describe progress toward our fourth year study objectives. Most of our effort was focused on estimating rates of fish injury and mortality associated with passage through the fish bypass facility and with fish trapping and hauling procedures at Westland Canal. We also estimated travel time, diversion rate, and drum and traveling screen leakage at this site. Other studies included (1) evaluating injury, mortality, and rate of travel associated with juvenile salmonid passage through the east-bank fish ladder at Three Mile Falls Dam and the headworks canal at the Maxwell Canal fish bypass facility, (2) conducting traveling screen impingement tests at the WEID Canal fish bypass facility, and (3) measuring water velocity in front of drum and traveling screens at Westland Canal, and drum screens at Maxwell and Feed canals.

STUDY SITES

Five major diversion dams in the lower Umatilla River are the focus of our long-range study plans (Figure 1). Another diversion dam (Dillon Dam) is located at River Mile 24.7. State-of-the-art adult and juvenile passage facilities were constructed at these dams between 1988 and 1993. All the juvenile fish bypass facilities share common structural and operational features. However, the need to meet site specific differences in facility function, canal capacity, topography, and river channel characteristics resulted in a unique design for each facility.

This year's field work was conducted at fish passage facilities at Westland (Figure 2), Three Mile Falls (Figure 3), Maxwell (Figure 4), and Feed Canal dams. Design of the WEID Canal juvenile fish bypass facility at Three Mile Falls Dam has been previously described (Knapp and Ward 1990, Knapp 1992, Cameron and Knapp 1993). Features common to the four sites include (1) canal headgates and checkgates and a bypass channel weir for regulating canal withdrawals, headworks water elevation, and bypass flow; (2) rotary drum screens and a bypass channel, downwell, pipe, and outfall to screen fish from the canal and return them to the river; and (3) a trash rack to intercept debris prior to entering the facility. Significant features not common to all the sites include (1) a wasteway channel to return excess water to the river (Westland and Maxwell), (2) pumps and associated traveling screens that provide a means of diverting excess water and increasing water velocity at the start of the bypass channel (Westland and WEID), and (3) fish trapping facilities for sampling or collection purposes (Westland and WEID).

Rotary drum screens at the juvenile fish bypass facilities are constructed of stainless steel wire cloth with approximately 0.125-inch-square mesh openings. Numbers and dimensions of drum screens at each site were designed to provide adequate screen surface area to meet screen water velocity criteria at maximum design canal flow (NMFS 1989, 1990). There are 10 6-feet-diameter x 12.4-feet-long screens at Westland Canal, 3 4-feet-diameter x 12-feet-long screens at Maxwell Canal, and 10 5-feet-diameter x 12-feet-long drum screens at Feed canal. Maximum design canal flow for the Westland, Maxwell, and Feed canals are 250 cfs, 50 cfs, and 300 cfs, respectively.

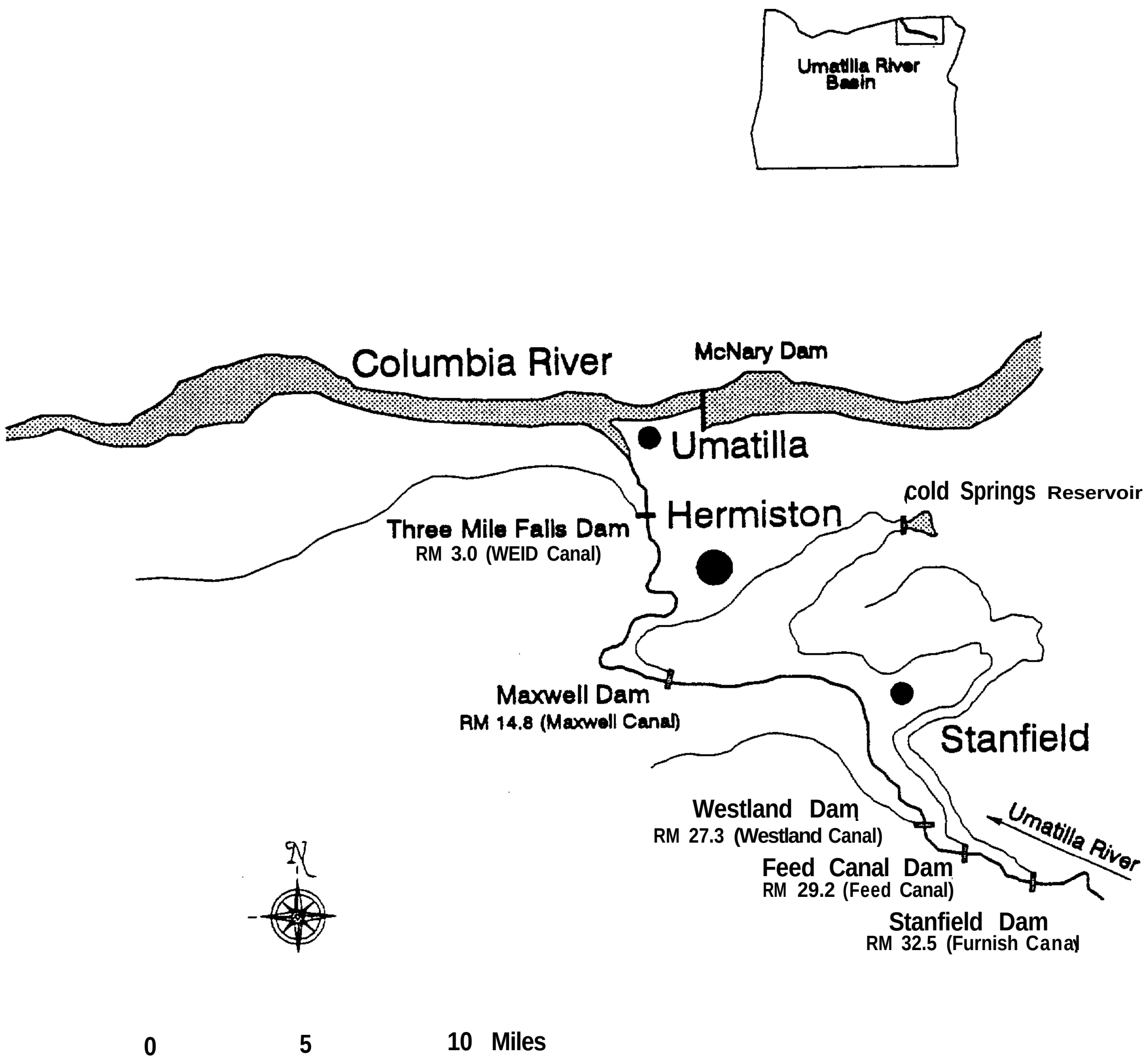
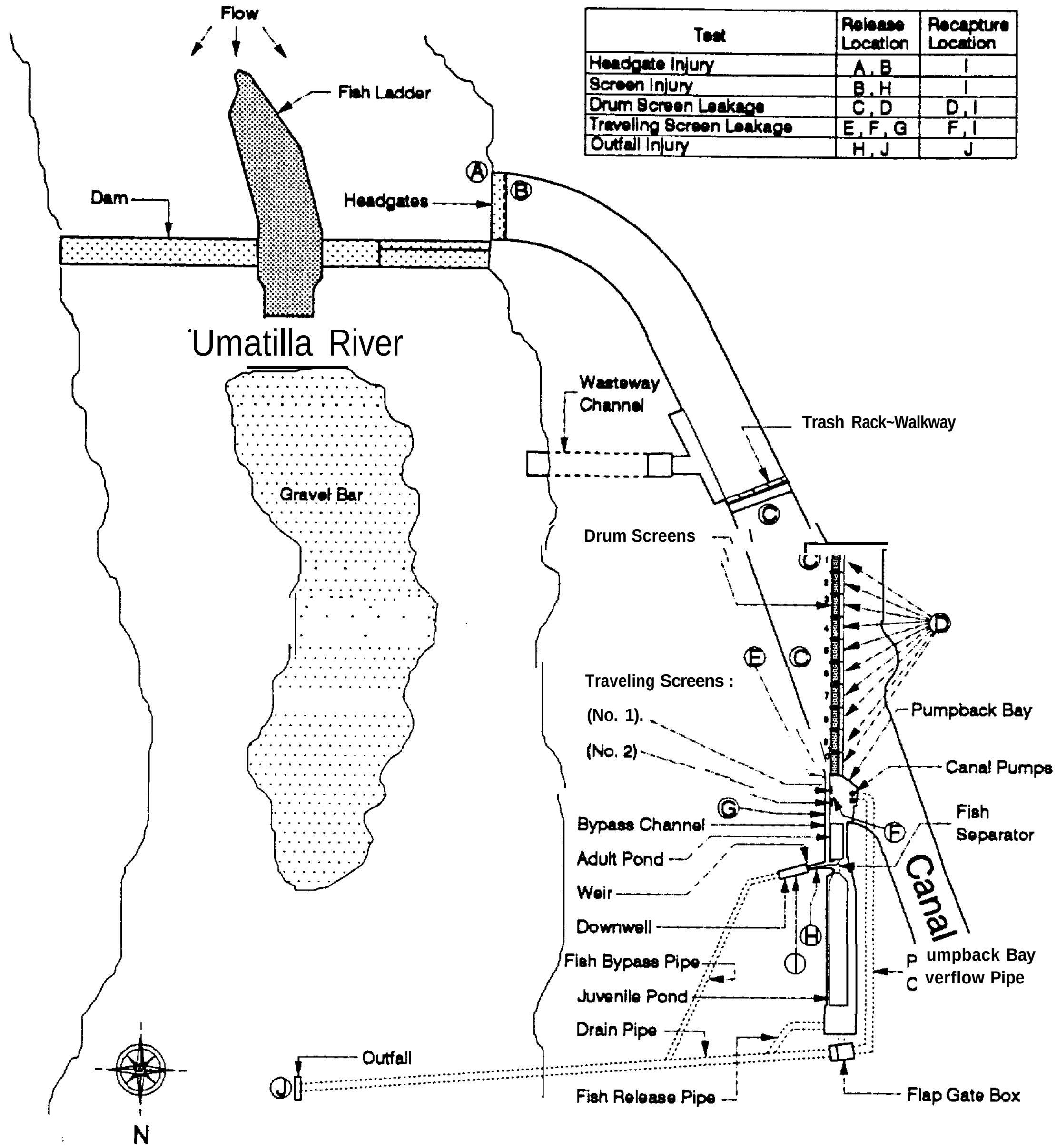


Figure 1. Locations of diversion dams and canals on the lower Umatilla River, Oregon.



Test	Release Location	Recapture Location
Headgate Injury	A, B	I
Screen Injury	B, H	I
Drum Screen Leakage	C, D	D, I
Traveling Screen Leakage	E, F, G	F, I
Outfall Injury	H, J	J

Figure 2. Schematic of the Westland Canal juvenile fish bypass facility at Westland Dam, Umatilla River, including locations for release and recapture of test fish. Not drawn to scale.

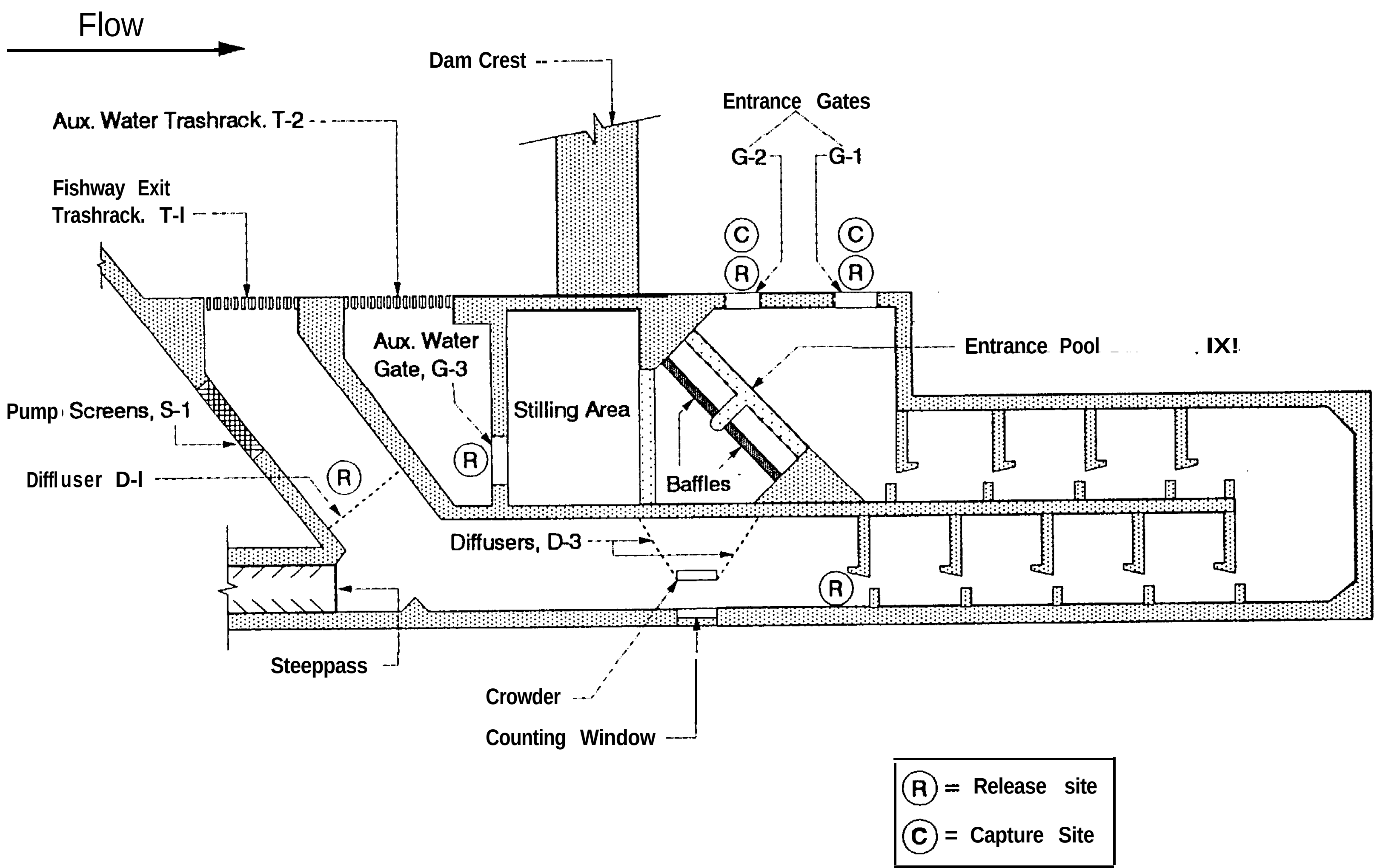


Figure 3. Schematic of the east-bank adult fish passage facility at Three Mile Falls Dam, Umatilla River, including locations for release and recapture of test fish.

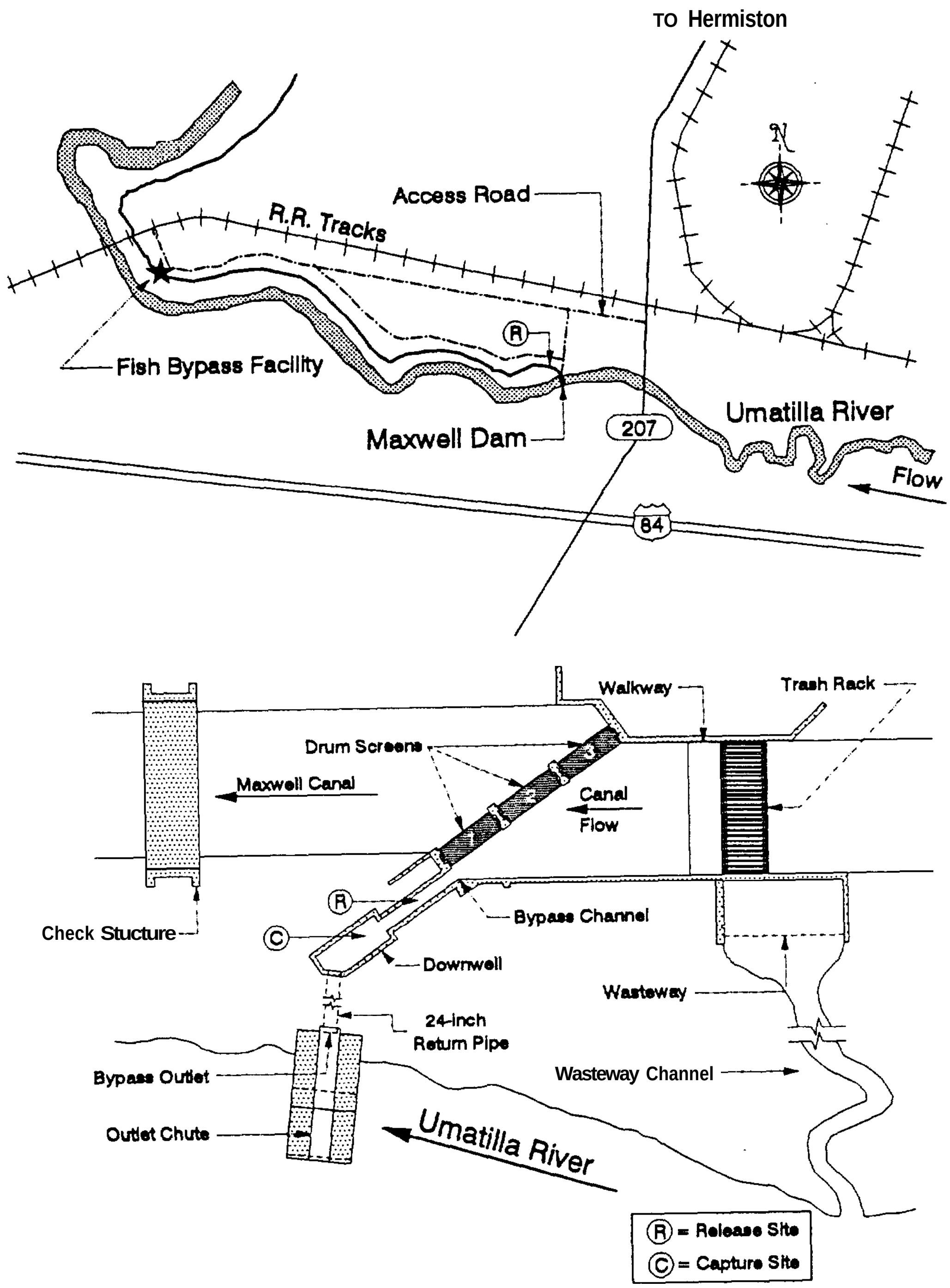


Figure 4. Schematic of the Maxwell Canal juvenile fish bypass facility at Maxwell Dam, Umatilla River, including locations for release and recapture of test fish.

Low river flow combined with water diversion for irrigation, water storage, or groundwater recharge may result in river conditions that are inadequate for salmon migration through the lower Umatilla River. When these conditions occur, ODFW and CTUIR (Trap and Haul Project) trap and transbort salmonids past sections of low river flow. The east-bank adult fish ladder at Three Mile Falls Dam and the Westland Canal juvenile fish bypass facility at Westland Dam are the primary trapping sites for migrating adult and juvenile salmonids, respectively.

Reconstruction of an existing fish bypass facility at Westland Dam and the addition of fish trapping facilities were completed in 1990. In 1992, automated headgates were installed and operated. Facility operating criteria have not been finalized for the Westland Canal juvenile fish bypass facility due to recent changes in the design and function of the facility, and ongoing revisions prompted by operating experience. Current facility operating criteria were issued by the National Marine Fisheries Service (NMFS) in response to repeated blockages of the bypass outlet by bedload movements caused by high river flows in 1993 (Appendix A). The Westland Canal juvenile fish bypass facility operates in either a fish bypass or trapping mode (Figure 2). Fish are bypassed until river flow is expected to drop below 150 cfs at Echo within 10 days (URTHP 1990). During fish bypass operations, bypass flow varies from the original design criteria of approximately 10 cfs (bypass channel weir 33% down) to maximum bypass flow of approximately 26 cfs (bypass channel weir fully lowered). Facility operation in a trapping mode includes (1) no flow to the downwell, (2) a full opening orifice slot behind each traveling screen, passing 6 cfs into'the pumpback bay, (3) passing 4 cfs into the juvenile holding pond, and (4) maintaining flow from the juvenile fish to adult fish holding ponds by evacuating water from the pumpback bay.

The WEID Canal juvenile fish bypass facility is operated in accordance with standard operating criteria developed by the NMFS (Cameron and Knapp 1993). Standard operation of the facility is to bypass 25 cfs of water when river flow past Three Mile Falls Dam exceeds 150 cfs. However, the facility will operate in a 5-cfs bypass flow mode to accommodate fish sampling, fish trapping, or to conserve irrigation water. Operation of canal pumps or opening the river-return drain pipe provide a means of removing excess water and increasing water velocity at the bypass channel entrance when the facility is operated in a 5-cfs bypass or sampling mode.

The east-bank fish ladder at Three Mile Falls Dam operates in accordance with standard operating criteria developed by the NMFS (Appendix A). The passage portion of the ladder provides a route for fish migration, whereas the auxiliary water portion increases flow through the fish entrance to help fish locate the ladder (Figure 3). Only one fish entrance gate is open when the adult fish passage facility is in operation. The low flow fish entrance gate (G-l) is open when river flow past the dam is less than 1,600 cfs.

The most significant feature of the Maxwell Canal juvenile bypass facility is 1.5 miles of canal extending from the headgates at Maxwell Dam to the fish bypass facility (Figure 4). The facility operates in one of three bypass modes depending on river flow (Appendix A). Bypass flow is set at approximately 9 cfs, 2 cfs, and 0 cfs when river flow past Maxwell Dam is high, near zero, and zero, respectively. Unlike all the other study sites, the drum screens at Maxwell Canal have been numbered in descending order from upstream to downstream.

U.S. Feed Canal, located at Feed Canal Dam, delivers irrigation storage water to Cold Springs Reservoir (50,000 acre-feet capacity). The canal operation generally extends from mid-November to mid-May. The juvenile fish bypass facility operates in accordance with standard operating criteria issued by the NMFS (Appendix A). Bypass flow is reduced from 18 cfs to 5.5 cfs when river flow no longer spills over the dam.

METHODS

Westland Dam and Canal

Traps

We visited the Westland Canal juvenile fish bypass facility at Westland Dam in late 1992 and early 1993 to design traps for use in upper and lower bypass injury tests scheduled in spring 1993. For the design of traps, we considered (1) ability to eliminate water from the trap and safely collect fish, (2) availability and suitability of structures to position the trap, (3) maximum water flow, (4) collection efficiency, and (5) accessibility. Design of the lower bypass trap needed to be flexible to permit use at other sites.

We used an inclined plane trap design to collect fish in the bypass downwell at Westland Canal (Figure 5). The design was patterned after that used for the bypass channel trap at Maxwell Canal (Knapp 1992). The Westland trap was designed to fit into guides located on the weir frame at the downwell entrance for positioning; a hoist system was built over the downwell for deployment and placement. The trap flared out from an opening of 20 inches to a width of 42 inches, with a total length of 6.5 feet. A pivot-rod front entrance assembly permitted leverage capabilities for adjusting water flow to the live box. The live box for fish capture and holding had a capacity of 19.1 gallons, and openings on 3 sides covered with perforated plate for eliminating excess water. Trap walls were solid 3/16-inch aluminum sheeting; the trap bottom was l/8-inch thick aluminum perforated plate with l/8-inch staggered holes (40% open). The trap floor was supported by longitudinal sections of l-inch aluminum angle irons welded to 2-inch aluminum strap cross pieces. Lifting brackets were welded onto the side walls and a lifting eye was incorporated into the front entrance assembly for raising and lowering the trap with chain hoists. The surface area of the perforated plate floor was designed to eliminate a 15-cfs bypass flow.

A fyke net and float system was used to capture fish at the bypass outlet (Figure 6). The net tapered from a square S-foot mouth to a circular 1.3-foot diameter opening to a net pen live box, over a length of about 20-feet. The net mouth frame, constructed of 2-inch x 2-inch wood reinforced with slotted angle steel, was attached to catamaran style floats supported by a wooden frame. A swivel type attachment of the net mouth frame to the catamaran aided deployment and transport of the trap. Metal eye-bolts installed along the top of each float assembly were used to hold ropes for trap positioning and securement.

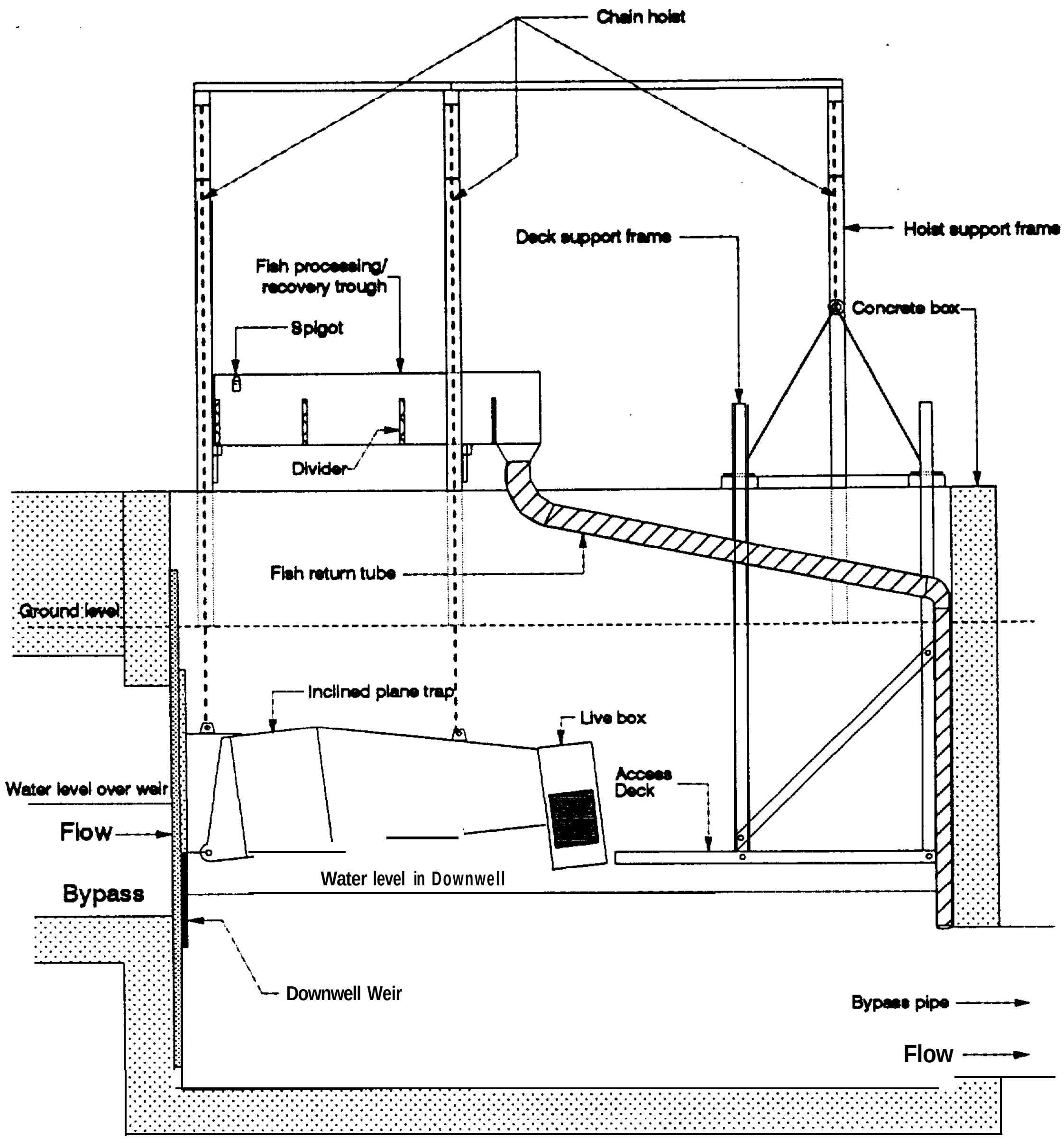


Figure 5. Inclined plane trap and fish processing station used to capture and examine test fish at the bypass downwell at the Westland Canal juvenile fish bypass facility at Westland Dam, Umatilla River, spring 1993.

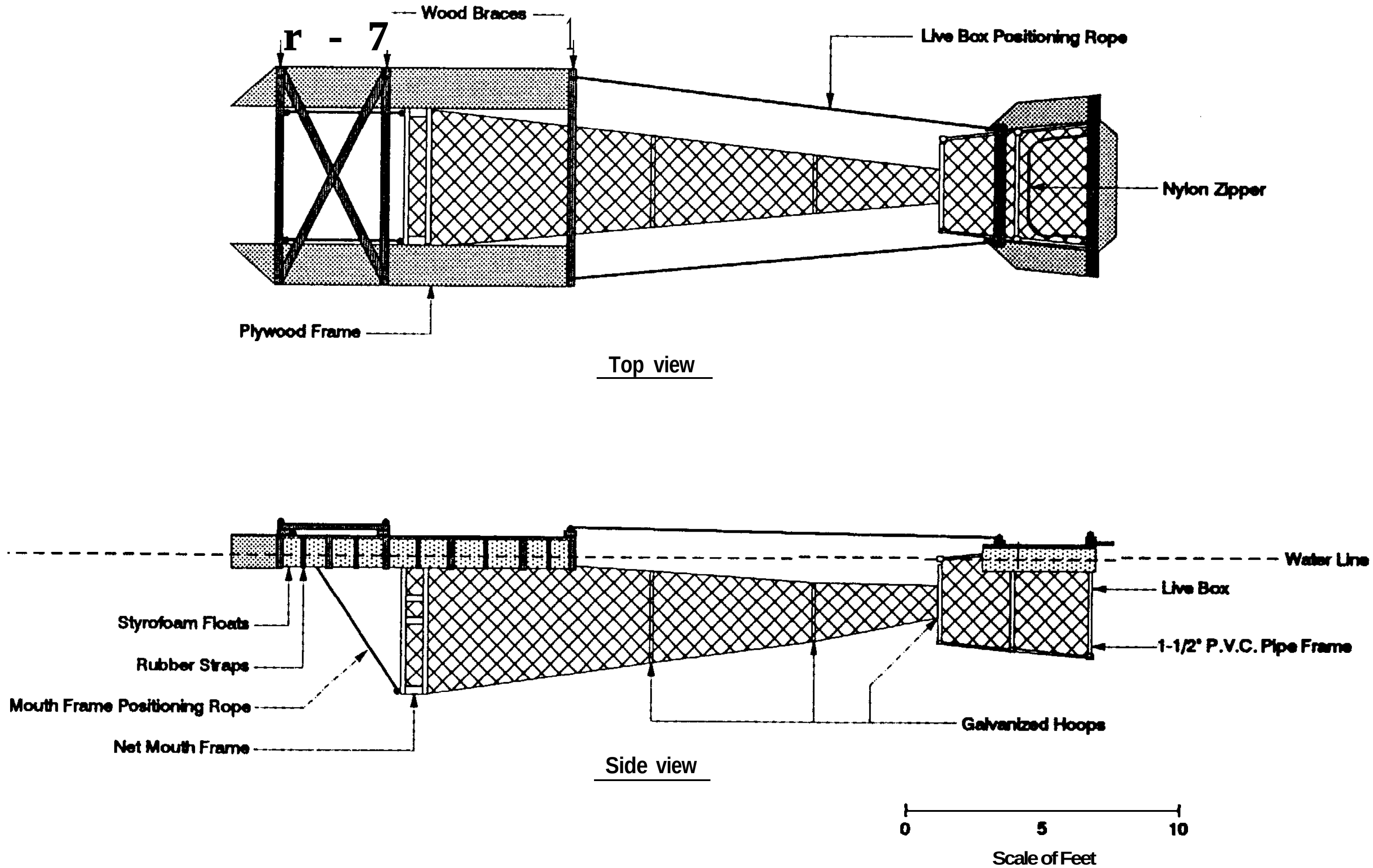


Figure 6. Floating fyke net and live box used to recapture test fish at the Westland Canal bypass outlet and the Three Mile Falls Dam (east-bank) ladder entrance gates, Umatilla River, spring 1993.

Injury

We examined rates of fish injury associated with passage through the facility and procedures to trap and haul fish. We conducted tests with fall and spring chinook salmon (0. tshawytscha) in April, May, and June of 1993. Hatchery fish designated for release in the Umatilla River were used in all but one test (Appendix Table B-3). River-run subyearling chinook salmon were used in the trap and haul evaluation. During all injury tests, the bypass operated according to revised criteria (Appendix Table A-l) developed by the National Marine Fisheries Service. We monitored water temperature in the canal headworks at a depth of 0.5 meters using a Taylor maximum-minimum thermometer.

Injury tests generally consisted of release and recapture of three replicate groups of marked treatment and control fish on three separate dates (Appendix Table B-l). Treatment fish were released upstream of the facility structure being evaluated; control fish were released either immediately downstream from the structure or in a recovery trap to assess collection efficiency and trap-caused injury. Test fish were recaptured in the middle or at the terminus of the bypass facility. Upper bypass and lower bypass refer to the portions of the fish bypass facility above and below the bypass channel weir, respectively (Figure 2). We used an inclined plane trap (Figure 5) attached to the bypass channel weir as the midpoint recovery site and a floating fyke net at the bypass outlet (Figure 6).

Test fish used in the facility evaluation were held 1 to 17 days in 600-gallon circular tanks prior to marking, then an additional 3 to 5 days in 4 feet x 2 feet x 2 feet net pens after freeze-branding. All test fish with common release sites and dates were held in the same net pen. A 20% subsample was collected from each treatment and control group of fish to obtain an estimate of pre-test condition (injury} and mean fork length. Fork lengths were measured to the nearest millimeter (mm). Subsampled fish were not returned to their groups or included in any test releases. Each treatment and control group consisted of approximately 150 fish prior to subsampling. All fish were handled in the same manner to reduce handling bias.

We assessed fish condition to estimate injury. Fish condition was determined using a modified version of the descaling criteria developed by the U.S. Army Corps of Engineers (Neitzel et al. 1985). We modified the descaling criteria by subdividing the partially descaled injury category (>3% and <40% scale loss) into low (> 3% and ≤ 20% scale loss) and moderate (> 20% and <40% scale loss) partial descaling. Fish injured but not descaled were designated as "otherwise injured."

Facility-caused injury was evaluated by comparing condition (injury rates) of treatment and control fish after recapture. Pre-test injury rates were subtracted from post-test injury rates to standardize initial injury rates for each release group. Pre-test injury rates (from subsamples) and post-test injury rates (from recaptured test fish) were calculated for each release group as the percentage of uninjured, low partly descaled, moderate partly descaled, otherwise injured, descaled, and dead fish. We multiplied the percentages of injury types by numerical factors to provide a qualitative measure of fish condition: uninjured (0.0), low partly descaled (0.167), moderate partly descaled (0.33), otherwise injured (0.33), descaled (0.67), and dead (1.0). Weighted injury was then calculated for each pre-test subsample and post-test release group as the sum of the weighted injuries for all injury categories. Net weighted injury was calculated by subtracting weighted injury of pre-test subsamples from the weighted injury of their corresponding post-test release group.

For all injury evaluations, paired T-tests were used to determine whether mean net weighted injury for treatment minus control was significantly greater than zero. We paired treatments and controls either by individual replicate groups or by day (replicates combined). We chose as our significance level (a) a P value of <0.10 using a one-tailed test of significance. We computed a 90% confidence interval about the mean difference between treatment and control net weighted injury rates. Assumptions of normality and homogeneity of variances were tested prior to conducting parametric statistical analysis. All testing was completed using the SAS program for personal computers (SAS Institute Inc. 1990).

Headgate Injury: We evaluated injury rates of spring and fall chinook salmon passing through the headgates during normal operation of the automated headgate system. Only Headgate 7 was open when tests were conducted with yearling spring chinook salmon from 15 April to 19 April 1993. Headgates 6 and 7 were open during the first releases of fall chinook salmon on 3 May 1993. Headgates 2 through 7 were open during the remainder of the tests with fall chinook salmon from 19 May to 21 May 1993. We released treatment fish close to shore, approximately 2 meters upstream of Headgate 1 (Appendix Table B-2). We used the treatment fish for the screen injury test (released downstream of the headgates) as the control for the headgate injury test.

Screen Injury: We evaluated injury rates of spring chinook and fall chinook salmon passing through the canal headworks and screen forebay. Screen injury tests were conducted concurrent with headgate injury tests (Appendix Table B-2). We released replicate groups of treatment fish at the tail of the headgate inflow turbulence at approximately two-hour intervals (Figure 2). Control groups were released immediately upstream of the bypass channel weir following each treatment release. Test fish were collected from the inclined plane trap at approximately 15-minute intervals. We operated the inclined plane trap continuously until most (> 85%) test fish were collected or no test fish were recaptured within an eight-hour period.

Bypass Pipe - Outfall Injury:. We evaluated yearling spring chinook salmon for injury associated with passage through the bypass pipe and submerged outlet from 23 April to 25 April 1993. Three groups of treatment fish were released at the bypass channel weir on three test dates (Appendix Table B-l). We released treatment groups at hourly intervals. We secured the floating fyke net within two meters of the outlet and collected fish from the live box at one-half hour intervals. We released approximately half of each control group into the mouth of the floating fyke net every half-hour after the first release of treatment fish.

Trap and Haul Injury: We evaluated injury to river-run subyearling chinook salmon associated with crowding and dip-net loading procedures at the juvenile fish pond from 16 June to 23 June 1993. Three groups of 100 fish were collected on three dates as they entered the pond (control), after pond crowding (Treatment 1), and after dip-net transfer (Treatment 2). Control fish entering the pond were collected with a fyke net and floating live box (Knapp 1992) one day prior to the collection of treatment fish. We collected treatment fish at the beginning, middle, and end of the crowding and loading procedures. Treatment 1 was collected by passing a submerged 5-gallon bucket through the area of the pond the fish had been crowded into. For Treatment 2, trap and haul personnel transferred dip-netted fish into a 20-gallon container placed next to the transport tank. We paired treatments and controls by day, and used Treatment 1 as the control for Treatment 2 in the data analysis. We also collected a single sample of 100 juvenile fish from the adult holding pond on 21 June 93.

Recovery and Travel Time

We recorded release and recapture times during injury tests to determine the average time for test fish to travel from a release point to a recovery point (travel time). We estimated travel time through the upper bypass by calculating the time to recapture 50% (median travel time) and 95% (95% travel time) of the test fish released. Percent recovery was based on the proportion of fish recovered by the end of the test (upper bypass tests) or within one hour (lower bypass tests). We used the Wilcoxon rank-sum test with a significance level of $P < 0.05$ to test whether differences in travel time and percent recovery among fish species were statistically significant. Nonparameteric analyses were used because the data were not normally distributed.

Diversion Rate

We estimated the rate of fish diversion from the river into the bypass as the percentage of test fish released above the headgates that were recaptured in the inclined plane trap at the conclusion of each headgate injury test.

Drum Screen Efficiency

We monitored passage of juvenile salmonids through (leakage) or over (impingement and roll-over) the drum screens at Westland Canal twice in 1993 to estimate drum screen efficiency. An initial screen efficiency test was conducted from 29 March to 4 April using fall chinook fry obtained from Umatilla Hatchery (Appendix Table B-3). All fry were right ventral clipped prior to use. During this test, the facility operated according to criteria, except the bypass was closed due to blockage. We also monitored the drum screens during the subyearling chinook salmon outmigration from 1 June to 4 June. During this period, facility operations were normal and the bypass flow was approximately 10 cfs.

For the drum screen efficiency test, we released the fall chinook fry in the screen forebay (treatment) and placed pairs of fyke nets (Cameron and Knapp 1993) on the downstream side of each drum screen to document leakage of fry (Appendix Table B-2). Three releases of test fry were made every other day. During each release, we released approximately 500 fry in the screen forebay in the morning and afternoon, and approximately 100 Bismark-brown dyed control fry downstream of each drum screen in the morning to estimate fyke net efficiency (Figure 2). We lifted the fyke nets out of the water to collect their contents at approximately 12-hour intervals. Fry holding between the drum screens and fyke nets were crowded toward each net prior to raising the net out of the water.

Individual drum screen efficiencies were calculated as the ratio of the number of treatment fry recaptured behind each drum screen (corrected for fyke net efficiency) to the number of fry that were guided past the screens. Data from paired fyke nets behind each drum screen was pooled to derive a single efficiency estimate for each screen. Separate drum screen efficiencies were calculated for all three test periods, then averaged to estimate overall mean screen efficiencies. We used the number of fish released during each test period for the number of fish that were guided past the screens (estimates for fish actually being guided past the screens could not be determined due to bypass closure and inability to collect fish downstream of the screens). We assumed net retention to be equal to net efficiency and gave it a value of 1.

The formula for calculating fyke net efficiency (EFF_{fn}) behind each drum screen was

$$EFF_{fn} = \frac{n_{fn1} + n_{fn2}}{N_{fn}}$$

where

n_{fn1} = the number of control fish captured in Fyke Net 1, and
n_{fn2} = the number of control fish captured in Fyke Net 2, and
N_{fn} = the number of control fish released at the fyke net mouths.

The formula for calculating percent drum screen efficiency (EFF_{ds}) was

$$EFF_{ds} = \left[1 - \frac{(X_{ds})}{(EFF_{fn} \times N_{fb})} \right] (100)$$

where

X_{ds} = the number of treatment fry recaptured behind the drum screen, and
N_{fb} = the number of treatment fry released in the screen forebay.

No releases of treatment or control fish were made during the outmigration monitoring in June. Fyke net contents were collected at 24 hour intervals during mid-day for four days. We calculated leakage (or roll-over) for each screen as the total number of juvenile salmonids captured behind each screen.

Traveling Screen Efficiency

Leakage of fall chinook salmon fry through the traveling screens was evaluated on 27 April and 29 April 1993 (Appendix Table B-2). The traveling screens were not operated according to NMFS criteria (Appendix Table A-l) because bypass operations were a higher priority at the time of testing. Operations consisted of full open orifice slots behind each traveling screen, one pumpback pump throttled to maintain a constant water level below the orifice slots, no flow to the holding ponds, and a bypass flow of approximately 18 - 20 cfs.

Treatment releases consisted of 600 fry to 800 fry, released in groups of 200 at hourly intervals at the bypass channel entrance. A fyke net was attached to each orifice slot to collect test fish that leaked through the traveling screens (Cameron and Knapp 1993). Fry that moved downstream past the traveling screens were recaptured at the downwell in an inclined plane trap. Bismark-brown dyed fry were used as controls in this test to estimate fyke net and bypass trap efficiency. Groups of 100 control fry were released in the bypass channel downstream of Traveling Screen 2 after each release of treatment fish to provide an estimate of bypass collection efficiency. Groups of 150 control fry were also released in each fyke net mouth to provide an estimate of fyke net efficiency. We'monitored the downwell trap on a continuous basis, and collected the contents of the fyke nets hourly. Tests were continued until the recapture of treatment fish exceeded 99%.

Individual traveling screen efficiencies were estimated from the number of treatment fry passing through each screen over the test period, corrected for trap and net efficiencies. We assumed that the total number of treatment fry encountering Traveling Screen 1 was equal to the sum of treatment fry recaptured in the downwell trap and Fyke Net 1. An estimate of the total number of treatment fry encountering Traveling Screen 2 was derived from the sum of treatment fry recaptured in the downwell trap and Fyke Net 2 minus the number of treatment fry captured in Fyke Net 1.

The formula for calculating each fyke net efficiency (EFF_{fn}) was

$$EFF_{fn} = \frac{nfn}{N_{fn}}$$

where

n_{fn} = the number of control fish captured in the fyke net, and
N_{fn} = the number of control fish released at the fyke net mouth.

The formula for calculating downwell trap efficiency (EFF_{dt}) was

$$EFF_{dt} = \frac{ndt}{N_{dt}}$$

where

ndt - the number of control fish captured in the downwell,' and
Ndt - the number of control fish released in the bypass channel downstream of Traveling Screen 2.

The formula for calculating percent screen efficiency for Traveling Screen 1 (EFF_{ts1}) was

$$EFF_{ts1} = \left[1 - \frac{\frac{X_{fn1}}{(EFF_{fn1})}}{\frac{(X_{fn1})}{(EFF_{fn1})} + \frac{(X_{dt})}{(EFF_{dt})}} \right] (100)$$

where

X_{fn1} = the number of treatment fry captured in the Fyke Net 1, and
X_{dt} = the number of treatment fry captured in the downwell trap.

The formula for calculating percent screen efficiency for traveling screen 2 (EFF_{ts2}) was

$$EFF_{ts2} = \left[1 - \frac{\frac{X_{fn2}}{(EFF_{fn2})}}{\frac{(X_{fn2})}{(EFF_{fn2})} + \frac{(X_{dt})}{(EFF_{dt})} \quad \frac{(X_{fn1})}{(EFF_{fn1})}} . \right] (100)$$

where

Xfn2 = the number of treatment fry captured in the Fyke Net 2.

Velocity and Flow Measurements

We collected velocity measurements at the Westland Canal drum and traveling screens following methods described by Cameron and Knapp (1993), using a Marsh McBirney (Model 201D) electromagnetic flowmeter. Measurements were assessed as to whether they met fish,screening criteria developed by the National Marine Fisheries Service (NMFS 1989, 1990).

Canal withdrawals were 195 cfs and 246 cfs during the drum screen velocity measurements on 24 May and 25 May 1993, respectively. We collected drum screen velocity measurements at 80% of water depth on 24 May and those at 20% and 50% of water depth on 25 May.

Velocity measurements were collected at both traveling screens on 26 May 1993. We simulated trapping operations during the measurements by (1) fully opening the orifice slot behind each traveling screen, (2) operating one pumpback pump throttled back to maintain the pumpback bay water elevation below the orifice slots, (3) stopping flow into the holding ponds, and (4) passing 4 cfs of flow over the bypass channel weir.

Bypass flows were computed from measurements of water surcharge over the bypass channel weir, corrected for side contractions at the weir (Prasuhn 1987). We used a standard formula for calculating flows at rectangular sharp-crested weirs (King and Brater 1963, Prasuhn 1987).

Three Mile Falls Dam and WEID Canal

Ladder Injury

We evaluated injury to yearling spring chinook and subyearling fall chinook associated with downstream passage through the east-bank adult fish passage facility at Three Mile Falls Dam. Tests with spring chinook salmon were conducted on 29 April with the high flow fish entrance gate (G-2) open and a total ladder flow of 161 cfs (Figure 3). Tests with fall chinook salmon were carried out on 17 May and 18 May with the low flow gate (G-l) open and a total ladder flow of 121 cfs to 124 cfs.

We made hourly releases of spring chinook salmon (treatment) approximately 2 meters downstream of the fishway exit and at the crest of the auxiliary water weir (gate G-3). Tests with fall chinook salmon included additional releases of treatment fish downstream of Diffuser D-3 to isolate injury associated with Diffusers D-l and D-3 (Figure 3). Treatment and control releases were made simultaneously, although control releases were split in two half-hour intervals. To recapture test fish, a floating fyke net (Figure 6) was deployed downstream of the open fish entrance gate (G-l or G-2), using a pulley and winch system.

Data analysis followed methods described for injury tests at Westland Dam and Canal (paired T-test). Treatment and control were paired by replicate groups in the analyses.

Recovery

We recorded the numbers of test fish. released and recaptured to determine recovery rates for all treatments and controls. Percent recovery was calculated as the proportion of each treatment or control recaptured by the conclusion of the test.

Traveling Screen Impingement

We evaluated impingement of fall chinook salmon fry on the traveling screens at the WEID Canal juvenile fish bypass facility from 7 April to 14 April 1993. Separate tests were conducted when both 10-cfs canal pumps were off and the river-return drain pipe was 20%, 30%, and 40% open and when the canal pumps were operated singularly and in tandem with the drain pipe closed. During operation of the traveling screen, the spray water wash was turned off. Screens were monitored continually after each release until most fish were recaptured.

Treatment releases consisted of 400 fry, released in groups of 100 at hourly intervals at the bypass channel entrance (Appendix Table B-l). We released 100 Bismark-brown dyed fry (control) immediately downstream of the 5-cfs orifice plate to determine trap collection efficiency. We assessed gross condition of fry during fin clipping and after the test to determine if injury occurred.

Maxwell Dam and Canal

Canal Injury

We evaluated injury rates of subyearling fall chinook salmon associated with passage through the headworks canal and screen facility at the Maxwell Canal juvenile fish bypass facility from 12 May to 14 May 1993. We released three groups of treatment fish in the canal approximately 25 meters downstream of the headgates during the day, evening, and nighttime hours (Appendix Table B-2). Treatment fish were contained in S-gallon buckets within a 250-gallon slip tanker for transport to the release site. An inclined plane trap was installed in the bypass downwell to recapture test fish (Knapp 1992). Control fish were released at the midpoint of the bypass channel to assess trap injury and collection efficiency. Data analysis followed methods described for injury tests at Westland Dam and Canal (paired T-test). Treatment and control were paired by day in the analysis.

Recovery and Travel Time

We followed the same methods for assessing travel time and percent recovery as described for recovery and travel time at Westland Dam and Canal. However, we analyzed the data collected at Maxwell Canal with ANOVA and compared differences in travel times among day, evening, and nighttime released fish using Duncan's multiple range test. We chose an a level of $P < 0.05$ in the analyses to determine statistical significance.

Velocity Measurements

We followed the same methods to measure water velocity in front of the drum screens and at the bypass channel entrance at Maxwell Canal as described by Cameron and Knapp (1993). Canal withdrawals were 39 cfs while collecting the measurements on 26 May 1993.

Feed Canal Dam and Feed Canal

Traps

Design of the inclined plane trap to be used in the Feed Canal bypass channel has been previously described (Hayes et al. 1992). We plan to reuse at Feed Canal the floating fyke net from our Westland Canal and Three Mile Falls Dam studies.

We followed the same procedure for designing fyke nets for the drum screen efficiency test as was used for fyke net design at Westland and WEID Canal (Knapp 1992, Cameron and Knapp 1993). However, fyke net frames were of a wood construction and a smaller size (12 feet wide x 6 feet high). Fyke nets were made of l/8-inch knotless nylon mesh with nylon encased edges. Nets tapered from the mouth opening to a E-foot-square cod end. Upstream and downstream side lengths were 17.7 feet and 7.2 feet, respectively. Nets were configured asymmetrically to allow them to conform to the direction of water flow. A zipper provides access to the cod end for fish and debris removal. Half-ton chain hoists will be used to raise and lower the nets.

Velocity Measurements

We generally followed the same procedure to measure approach and sweep water velocities in front of the drum screens at Feed Canal as was used at Westland Canal (Cameron and Knapp 1993). However, mid-water depth measurements were taken at 60% water depth instead of 50% water depth. We used the same method for measuring approach velocity at the bypass channel entrance as was used at the WEID Canal (Cameron and Knapp 1993). Water withdrawals at Feed Canal were at normal capacity (211 cfs) while collecting velocity measurements on 16 May 1993.

RESULTS

Westland Dam and Canal

Injury

The Westland Canal juvenile fish bypass facility caused few injuries to juvenile salmonid test fish that traveled past the screens or through the headgates, downwell, bypass pipe, and outlet (Table 1). Difference in mean, net weighted injury rates between treatment and control fish did not exceed 1.7 and none of the differences were significantly greater than zero (P > 0.10) However, the mean difference in injury rates of treatment and control fish approached statistical significance in the screen injury test with spring chinook salmon (T = 1.47, P = 0.14). Low and moderate partial descaling were the predominant types of injuries observed during this test. Fall chinook salmon were in better condition than spring chinook salmon prior to release, and generally only incurred low partial descaling after release. In addition, the differences in mean injury rates of recaptured treatment and control fish in screen injury tests was lower for fall chinook salmon (0.3) than spring chinook salmon (1.5).

Table 1. Results of injury tests conducted at Westland Dams during the 1993 Umatilla River juvenile fish passage evaluation (pre-test values are in parentheses; N = number of test replicates).

Species[a]	Test[b]	Treatment or control[c]	Number released	Number recaptured	Mean percentage of fish recaptured: Low descaling	Moderate descaling	Descaled	Other	Mortality	Treatment minus control: Mean net weighted injury	90% confidence limit	Probability[d]	N
JUVENILE FISH BYPASS FACILITY AT WESTLAND DAM													
CHF	HIT	Treatment	259	172	38.2 (8.3)	1.7 (0.0)	0.6 (0.0)	0.0 (0.0)	0.0 (0.0)	1.7	± 4.7	p = 0.23	2
CHF	HIT	Control	246	242	30.6 (1.7)	0.0 (0.0)	0.0 (0.0)	0.0 (3.5)	0.0 (0.0)				2
CHS	SIT	Treatment	1052	1027	55.5 (36.8)	8.9 (3.0)	0.7 (0.4)	0.2 (0.0)	0.1 (0.0)	1.5	± 1.9	p = 0.14	3
CHS	SIT	Control	1018	1015	49.4 (39.8)	5.5 (4.7)	0.9 (0.4)	0.0 (0.0)	0.1 (0.0)				3
CHF	SIT	Treatment	a47	al4	26.3 (14.9)	0.0 (0.5)	0.0 (0.0)	0.1 (1.0)	0.1 (0.0)	0.3	± 1.0	p = 0.37	7
CHF	SIT	Control	1085	1072	19.6 (14.8)	0.4 (0.0)	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)				7
CHS	BOIT	Treatment	1125	412	20.6 (21.2)	3.0 (0.4)	0.0 (0.0)	0.9 (2.9)	0.6 (0.0)	0.9	± 1.8	p = 0.25	9
CHS	BOIT	Control	997	726	12.4 (17.1)	0.6 (0.0)	0.2 (0.0)	0.0 (0.4)	0.7 (0.0)				9
CHS/F	T&H	Treatment (Dip-net)	--	900	33.2	7.2	2.3	0.0	0.0	1.7	± 2.1	p = 0.13	3
CHS/F	T&H	Treatment (Crowd)	--	868	26.9	4.6	2.7	0.1	0.0	0.3	± 4.5	p = 0.46	3
CHS/F	T&H	Control (Pond)	--	900	24.9	4.5	2.6	0.1	0.0				3
CHS/F	T&H	Adult pond	--	100	48.0	14.0	4.0	0.0	0.0				1

a CHS = yearling spring chinook salmon, CHF = subyearling fall chinook salmon, CHS/F = subyearling spring and fall chinook salmon.
b HIT = headgate injury test, SIT = screen injury test, BOIT = bypass outlet injury test, T&H = trap and haul evaluation.
c SIT treatment was the control for HIT treatment, Treatment (Crowd) was the control for Treatment (Dip-net).
d Risk of error if rejecting H_o: (T - C) = 0 in favor of alternative H_a: (T - C) > 0,

Variation among the differences in injury rates of paired treatment and control groups was generally low in the bypass injury tests. The one exception was attributable to a small sample (N = 2) in the headgate injury test (Table 1). Trap-caused injury was also very low during all the tests (12.1%).

Few mortalities were recorded in either the upper or lower bypass tests. Injuries categorized as "other" in the upper bypass tests consisted equally of bloody eyes, bird marks, cuts or bruises, and head injuries. Other injuries recorded in the lower bypass were attributable to pre-test condition and consisted of bloody eyes and cuts or bruises.

Mean fork lengths of test fish are included in Appendix Table C-l. Water temperature at a depth of 0.5 meters in the canal headworks ranged from 44°F to 66°F throughout the period when injury tests were conducted (Appendix Figure C-l).

Trap and haul procedures at the Westland Canal juvenile fish bypass facility caused some injury to juvenile chinook salmon (Table 1). The mean weighted injury rate of crowded fish (treatment) compared to pond fish (control) was not significantly different ($T = 0.11$, $P = 0.46$). However, estimates of the condition of fish entering the pond were highly variable. On two of the three sampling dates, injury rates of fish entering the pond were estimated to be higher than the injury rates of crowded fish. The difference in mean injury rates between dip-netted and crowded treatments was less variable, and almost statistically significant ($T = 1.52$, $P = 0.13$). The weighted injury rate of juvenile fish collected from the adult pond was more than twice that of fish dip-netted from the juvenile pond (Table 1).

Recovery and Travel Time

Recovery rates and median travel time were low for fish released upstream of the headgates (Table 2). Of the fall chinook salmon groups released, only 2 of 5 achieved 50% recovery. Median travel time averaged 0.5 hours for these two replicates. Although this travel time was lower than the mean for all seven replicates of fish released downstream of the headgates (1.2 hours), some downstream release groups did travel faster (0.3 hour median travel time). Only 0.2% of the spring chinook salmon released above the headgates were recaptured.

Time to recover 50% of spring and fall chinook salmon groups released downstream of the headgates ranged from approximately 0.2 hours to 3.0 hours. The median travel times of the two species were not significantly different ($T = 59.0$, $P > 0.05$; Table 2). Only 5 of 7 fall chinook salmon groups and 7 of 9 spring chinook salmon groups released downstream of the headgates reached a recovery rate of 95% by the end of the test. Fall chinook salmon reached a 95% recovery in less than half the time (7.8 hours) it took to recover 95% of the spring chinook salmon (16.0 hours). Although the time difference was sizable, it was not statistically significant ($T = 28.0$, $P > 0.05$). The range of time to reach 95% recovery was also higher for groups of spring chinook

Table 2, Travel time, determined as the number of hours to recapture 50 percent (median) and 95 percent of test fish released in the upper bypass, and the percentage of test fish recaptured by the end of each test at the Westland Canal and Maxwell Canal juvenile fish bypass facilities, Umatilla River, spring 1993.

Species	Bypass section	Release site[a]	Capture site[b]	Bypass flow (cfs)	Canal flow (cfs)	50% Travel time (hours) mean	SD	N	95% Travel time (hours) mean	SD	N	Percent recapture mean	SD	N
WESTLAND CANAL JUVENILE FISH BYPASS FACILITY														
CHF	Upper	U-H	DT	18-20	195-267	0.5	0.1	2	--	--	0	28.2	35.0	5
CHF	Upper	D-H	DT	18-20	195-267	1.2	1.0	7	7.8	6.2	5	96.3	3.5	7
CHS	Upper	U-H	DT	18-20	57-90	--	--	0		--	0	0.2	0.4	9
CHS	Upper	D-H	DT	18-20	57-90	1.3	0.9	9	16.0	17.0	7	95.8	5.1	9
CHS	Lower	BCW	OT	22-26	--	--	--	--	--	--	--	36.1	10.6	9
MAXWELL CANAL JUVENILE FISH BYPASS FACILITY														
CHF	Upper	D-H	DT	Y-10	14-29	2.9	0.8	9	--	--	0	78.8	7.7	9
By release times:														
Day releases						3.6	0.8	3	--	--	0	70.3	4.7	3
Evening releases						2.6	0.6	3	--	--	0	85.7	2.1	3
Night releases						2.6	0.7	3	--	--	0	80.3	5.5	3

[a] U-H = upstream of headgates, D-H = downstream of headgates, BCW = bypass channel weir.
[b] DT = downwell trap; OT = outfall trap.

salmon (3.4 hours to 43.2 hours) than fall chinook salmon (1.0 hours to 16.4 hours). Mean percent recapture for groups of fall chinook and spring chinook salmon slightly exceeded 95% and were not significantly different ($T = 58.5$, $P > 0.05$; Table 2).

Most spring chinook salmon released at the crest of the downwell weir were not recaptured at the bypass outlet (Table 2). Percent recapture of replicate groups of spring chinook salmon averaged 36.1% after approximately one hour of sampling at the bypass outlet. Percent recapture (and sampling intervals) for test replicates ranged from 22.7% (0.8 hours) to 57.9% (1.3 hours). Most fish were recaptured within one-half hour of release; very few additional fish were recovered when sampling extended beyond one hour.

Diversion Rate

Few test fish released upstream of the headgates were diverted into the canal (Table 2; Figure 7). Mean diversion rates for fall chinook and spring chinook salmon were 28.2% and 0.2%, respectively. Only 2 of about 1,000 spring chinook salmon released upstream of the headgates were recaptured at the downwell by the conclusion of the test. Less than 5% of each replicate group of fall chinook salmon were diverted into the canal on all dates, except 3 May when Headgates 6 and 7 were open. On this date, the diversion rates for the 3 replicates ranged from 4% to 68%. The higher diversion rates of test fish on 3 May coincided with the largest numbers of river-run fish collected during any of the tests conducted in the upper bypass (Figure 7).

Drum Screen Efficiency

Less than 0.5% of the 2,975 fall chinook fry released in the screen forebay leaked through the drum screens from 29 March to 4 April 1993 (Table 3). The greatest numbers of fry (5) leaked through the end screens (1 and 10). Leakage also occurred at Drum Screens 4, 5, and 9. Mean fork length of fry that leaked through the drum screens (53.5 mm) was slightly less than fry released in the screen forebay (56.6 mm). Screen efficiency estimates ranged from 99.81% to 100%. Gravel deposition at the bypass outlet during the test precluded water flow through the bypass as well as diversion and collection of treatment fry at the downwell. Canal withdrawals were 41 cfs on the first two days of the test, then increased to 51 cfs through the remainder of the test. Fry impingement or roll-over was not observed. Maximum and minimum water temperatures ranged from 42^{o} F to 52^{o} F during the tests.

During the subyearling outmigration, we collected 15 subyearling chinook salmon downstream of the drum screens during 4 days of monitoring from 1 June to 4 June 1993 (Table 3). Most fish were recaptured behind screens close to the bypass channel entrance (10 and 8). Mean fork length of fish recaptured was 103.0 mm. Canal withdrawals were near design capacity (250 cfs) throughout the monitoring period. Although fish impingement or roll-over was not observed during the test, fish recaptured were dead or moribund and fungused, indicating roll-over had occurred. Maximum and minimum water temperatures ranged from 57^{o} F to 70^{o} F during the tests.

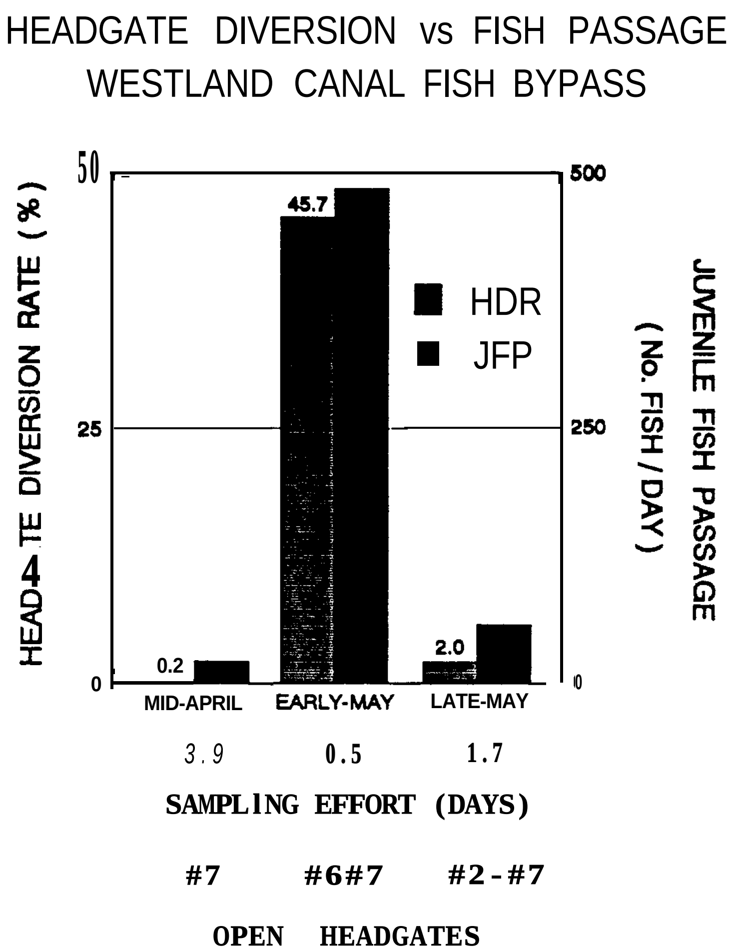


Figure 7. Percent diversion of test fish through the headgates (HDR) and numbers of river-run juvenile salmonids captured (JFP) during headgate injury tests at the Westland Canal juvenile fish bypass facility at Westland Dam, Umatilla River, spring 1993. Percent headgate diversion (top of bars), number of days sampled, and open headgates for each test period are included.

Table 3. Evaluations of drum screen efficiency with fall chinook salmon fry, and leakage and roll-over during the subyearling chinook salmon outmigration at the Westland Canal juvenile fish bypass facility, Westland Dam, Umatilla River, spring 1993. Bypass flow was 0 cfs during the fry leakage evaluation and approximately 10 cfs during the subyearling migration.

	29 March - 4 April (2,975 CHF fry released in headworks)			1 June - 4 June (Subyearling migration)	
Drum screen no.	Mean fyke net efficiency (percent)	Screen efficiency (percent)	Corrected leakage & mean fork length (mm)	Leakage or roll-over (no. CHF)	Mean fork length (mm).
1	63	99.81	5 (49.2)	1	--
2	76	100	0	--	--
3	86	100	0	--	--
4	73	99.96	1 (54)	--	--
5	82	99.91	2 (59.5)	--	--
6	76	100	0	--	--
7	98	100	0	1	103
8	97	100	0	5	--
9	93	99.97	1 (65)	2	99.5
10	92	99.82	5 (52.2)	6	102.8
Overall mean:	83.5	99.95	1.5 (53.5)	1.5	103.0
Ranse					
Minimum:	37	99.56	0 (32)	0	75
Maximum:	100	100	5 (65)	6	126

Traveling Screen Efficiency

Both traveling screens were 100% efficient in preventing fall chinook salmon fry leakage into the pumpback bay during simulated trapping operations. High trap efficiencies were recorded for the downwell trap (98.3%), and the fyke nets installed behind Traveling Screens 1 (73.7%) and 2 (99.3%). Trap efficiencies were nearly identical on both days. Mean fork length of test fry was 62.7 mm (Appendix Table C-l). Water temperatures ranged from 48° F to 54° F during the tests.

Velocity and Flow Weasurements

Drum Screens: Approach water velocities at the drum screens were not uniform, ranging from -1.55 feet per second (fps) to 0.86 fps (Table 4). Mean approach velocities at 20%, 50%, and 80% of water depth steadily increased from -0.38 fps, -0.09 fps, to 0.24 fps, respectively. Only 13 of the 90 sampling locations had velocities exceeding criteria (0.4 fps) for salmonid fry; one location exceeded the approach velocity criteria (0.8 fps) for salmonid fingerlings. Most velocity measurements exceeding criteria were recorded at Screens 8, 9, and 10, located near the bypass channel entrance. Upstream transects of Screens 1 and 10 and the downstream transect of Screen 10 had the highest mean approach velocities.

Sweep velocities were generally twice the magnitude of approach velocities at all locations, except at 80% of water depth where they were lower (Table 4). Mean sweep velocity steadily declined from 1.77 fps at 20% water depth to 1.56 fps (50% water depth), to 0.73 fps (80% water depth). Sweep velocities ranged from 0.10 fps to 2.40 fps, and were highest at Screens 5 through 10 at 50% water depth and above.

Traveling Screens: Approach velocities in front of the traveling screens were well below the 0.4 fps criteria in all sampling locations, except the upstream transect of Screen 1 (Table 5). With water depths combined, mean approach velocity at this transect was 0.73 fps compared with -0.12 fps for all other sampling locations.

Sweep velocity was twice the magnitude of approach velocity at all locations, except the upstream transect of Screen 1 (Table 5). The highest sweep velocities were generally measured near the water surface (20% water depth) at the upstream transects and near the bottom (80% water depth) at the downstream transects of both screens. With all water depths combined, mean sweep velocity was 0.78 fps and 0.54 fps for Screens 1 and 2, respectively.

Bypass Channel: Approach velocities at the bypass channel entrance exceeded 3 fps at the two weir settings (30% raised and full down) and were highest near the water surface (Table 6). Average velocities were 3.22 fps and 3.74 fps when the bypass channel weir was 30% raised and full down, respectively.

Computed bypass flows ranged from approximately 8 cfs when the bypass weir was 70% raised to a maximum of 26 cfs when the weir was full down (Appendix Figure C-Z). Approximately 19 cfs passed into the bypass downwell when the weir was 30% raised (passage evaluation bypass operation).

Table 4. Mean sweep and approach velocities (fps) at the Westland Canal drum screens, Umatilla River, spring 1993. Drum screens are numbered in ascending order from upstream to downstream. Canal flow was 195 cfs to 246 cfs. Bypass flow was approximately 22 cfs to 26 cfs.

Drum screen no.	Transect	Sweep velocity: Percent of water depth 20%	50%	80%	Approach velocity: Percent of water depth 20%	50%	80%
1	Upstream	1.32	1.12	.84	.41	.35	.72
2	Upstream	1.58	1.65	.50	-.1O	.32	.35
3	Upstream	1.59	1.35	.78	-.53	.75	-.28
4	Upstream	1.95	1.25	.55	-.35	.37	.20
5	Upstream	2.05	1.65	.45	-.60	.40	.58
6	Upstream	1.90	1.60	1.05	-.63	.38	.35
7	Upstream	2.10	1.70	.95	-.35	-.55	.38
8	Upstream	1.75	1.40	.34	-1.05	-.85	.54
9	Upstream	2.20	1.75	.41	.15	-.47	.29
10	Upstream	1.65	1.35	.51	.86	.80	.1l
1	Middle	1.29	1.41	1.05	-.25	.05	.29
2	Middle	1.47	1.32	.90	-.20	-.05	.oo
3	Middle	1.75	1.60	1.10	-.35	.25	-.44
4	Middle	1.82	1.35	.60	-.35	.53	.25
5	Middle	1.70	1.65	.95	-.57	.05	.30
6	Middle	2.10	1.60	1.34	.25	-.23	-.04
7	Middle	2.00	1.00	.90	-.25	-.65	-.30
8	Middle	2.15	2.40	.65	-1.40	-1.05	.74
9	Middle	2.05	2.00	.61	-.85	-.70	.71
10	Middle	1.70	1.50	.40	-.60	.48	.28
1	Downstream	1.42	1.63	.90	-.1l	-03	.25
	Downstream	1.55	1.72	.78	-.32	-.23	-.1O
:	Downstream	1.60	1.70	.53	-.55	.oo	.20
4	Downstream	1.87	1.15	.65	-.65	.20	.08
5	Downstream	2.05	2.00	.1O	-.73	-.50	.13
6	Downstream	2.10	1.90	.92	-1.45	-1.55	.35
7	Downstream	1.75	1.55	1.25	-.45	-.45	-.12
8	Downstream	1.40	1.90	-58	-.66	-.75	.67
9	Downstream	2.00	1.95	.96	.60	-.15	.24
10	Downstream	1.15	.75	.35	.33	.55	.35

Table 5. Sweep and approach velocities (fps) at the Westland Canal traveling screens during simulated trapping operations[a], Umatilla River, spring 1993. Traveling screens are numbered in ascending order from upstream to downstream.

Traveling screen no.	Transect	Sweep velocity: Percent of water depth 20%	50%	80%	Approach velocity: Percent of water depth 20%	50%	80%
1	Upstream	.91	.90	.52	.85	.76	.57
1	Middle	.93	.87	.72	.lO	-.23	-.68
1	Downstream	.61	.68	.92	-.15	-.14	-.62
2	Upstream	.81	.67	.66	.29	-.02	-.54
2	Middle	.46	.39	.67	.21	.25	-.lO
2	Downstream	.16	.27	.73	.oa	.lO	-.32

[a] Facility trapping operations were simulated by fully opening the orifice slots behind the traveling screens to pass a total of 6 cfs into the pumpback bay, and the downwell weir 7owered 9" below normal water level to pass 4 cfs into the downwe77.

Table 6. Approach velocities (fps) at the bypass channel entrance at Westland Canal at varying downwell weir settings, and at Maxwell and Feed Canals at standard operations, Umatilla River, spring 1993.

Bypass facility	Facility operation	Bypass channel weir setting	Canal flow (cfs)	Bypass flow (cfs)	Approach velocity: Percent of water depth 20%	50%	80%
Westland	1993 criteria (passage evaluation)[a]	30% raised	246	18 - 20	3.34	3.31	3.02
Westland	1993 criteria,, (bypass mode)	Full down	246	22 - 26	3.95	3.85	3.43
Maxwell	1990 criteria (normal operation)[c]	1.5' spill	39	8 - 10	2.22	2.30	2.49
Feed	1990 criteria (normal operation)[d]	1.5' spill	211	18	2.95	3.04	3.06

[a] *NMFS revised bypass operating criteria: downwell weir raised 30%.*
[b] *NMFS revised bypass operating criteria: downwell weir full down.*
[c] *NMFS normal bypass operating criteria: 1.5 feet of spill over downwell weir.*
[d] *NMFS normal bypass operating criteria when there is spill over dam: 1.5 feet of spill over downwell weir.*

Three Mile Falls Dam and WEID Canal

Ladder Injury

Yearling spring chinook salmon received few injuries as a result of downstream movement through either the passage or auxiliary water portion of the east-bank fish ladder (Table 7). Mean, net weighted injury rates were higher for control fish than treatment fish released upstream of Diffuser D-l or at the auxiliary water weir. Treatment fish were not released downstream of Diffuser D-3 during this test. The difference between mean injury rates of the treatment and control fish was not significant for treatment fish released in either the passage (T = -0.58, P = 0.81) or auxiliary water (T = -1.31, P = 0.66) portions of the ladder. Roughly half of all test fish had low amounts of descaling prior to release. After recapture, the proportion of moderate partial descaling increased. Less than 1% of fish recaptured were dead or had other types of injuries. Mean fork length of test fish was 128.3 mm (Appendix Table C-l).

In contrast, subyearling fall chinook salmon that moved downstream through the passage portion of the east-bank ladder received high amounts of injury (Table 7). The difference in mean injury rates between treatment fish released upstream of Diffuser D-l and control fish released downstream of Diffuser D-3 were significant (T - 3.17, P = 0.04). The difference in mean injury rates between treatment fish and control fish released into the fyke net were significant for treatment fish released downstream of Diffuser D-3 (T = 19.31, P - O.OOl), but not for treatment fish released at the auxiliary water weir (T = 0.57, P - 0.30). Test fish incurred twice as much injury traveling between Release Sites UD-1 and DD-3 than from Release Site DD-3 to the fyke net. Fish recaptured from passage side releases (UD-1 t DD-3) exhibited increased proportions of moderate partial descaling (2.1% - 2.5%), complete descaling (6.6% - 19.2%), and mortality (2.5% - 3.2%) compared to control fish condition. Fish recaptured from releases made at the auxiliary water weir exhibited increased proportions of low partial descaling (5.7%) and mortality (0.8%) compared to control fish condition. Mean fork length of test fry was 82.3 mm (Appendix Table C-l).

Recovery

Spring chinook salmon released at the auxiliary water weir were recaptured sooner and more extensively than fish released in the passage side of the ladder. We generally did not recapture fish released above Diffuser D-1 until an hour after their release; afterwhich they were steadily recaptured in relatively small numbers. Only 17% of the fish released above Diffuser D-l were recaptured by the end of the test. Fourty-three percent of the chinook salmon released at the auxiliary water weir were recaptured, mostly within one hour. Seventy-seven percent of the control fish released in the mouth of the fyke net were recollected.

Recovery rates of fall chinook salmon from the passage and auxiliary water portions of the ladder paralleled those for spring chinook salmon. We recaptured 75% of the control fish, and 28%, 71%, and 62% of the treatment fish released upstream of Diffuser D-l, downstream of Diffuser D-3, and at the auxiliary water weir, respectively.

Traveling Screen Impingement

We observed some impingement of fall chinook salmon fry on the traveling screen at the WEID Canal juvenile fish bypass facility when the river-return drain pipe was open 40% with both canal pumps off, and when both canal pumps operated with the drain pipe closed. Percent impingement, corrected for trap collection efficiency, was less than 1% when the pumpback bay was operated with the drain pipe 40% open (0.56%) or both canal pumps on (0.13%). All impingement that occurred during testing was observed along the downstream edge of the screen.

Injuries fry received as a result of being pinned on the screen were more serious when the drain pipe was open 40%. Two of,three fry impinged during the drain pipe operation were caught between the screen and side-seal and carried to the top of the seal by the rotating screen. Both fry died from

Table 7. Results of injury tests conducted at Three Mile Falls and Maxwell dams during the 1993 Umatilla River juvenile fish passage evaluation (pre-test values are in parentheses; N = number of test replicates).

Species[a]	Test[b]	Treatment[c] or control	Release[d] site	Number released	Number recaptured	Mean percentage of fish recaptured: Low descaling	Moderate descaling	Descaled	Other	Mortality	Treatment minus control: Mean net weighted injury	90% confidence limit	Probability[e]	N
(EAST-BANK) ADULT FISH PASSAGE FACILITY AT THREE MILE FALLS DAM														
CHS	LIT	Treatment	UD-1	386	65	58.4 (55.3)	10.3 (2.2)	1.3 (1.1)	0.0 (1.1)	0.0 (0.0)	-2.5	± 8.1	p = 0.81	3
CHS	LIT	Treatment	AWG	540	232	64.3 (61.3)	5.1 (5.3)	0.8 (2.2)	0.4 (0.0)	0.9 (0.0)	-1.3	± 1.9	p = 0.66	3
CHS	LIT	Control	G-2	432	331	57.6 (55.0)	17.4 (6.9)	1.9 (0.0)	0.0 (0.0)	0.5 (0.0)				3
CHF	LIT	Treatment	UD-1	586	164	44.5 (45.6)	10.2 (1.1)	32.8 (0.0)	0.0 (0.0)	3.7 (0.0)	8.1	± 4.8	p = 0.04	3
CHF	LIT	Treatment	DD-3	534	378	51.7 (43.0)	9.8 (1.1)	20.2 (0.0)	0.0 (0.0)	3.0 (0.0)	4.3	± 0.4	p = 0.001	3
CHF	LIT	Treatment	AWG	715	444	47.9 (39.1)	6.7 (0.0)	11.4 (0.0)	0.0 (0.7)	1.3 (0.0)	0.5	± 1.4	p = 0.30	4
CHF	LIT	Control	G-l	742	556	45.1 (42.0)	6.9 (0.3)	14.3 (0.7)	0.0 (0.0)	0.5 (0.0)				3/4
JUVENILE FISH PASSAGE FACILITY AT MAXWELL DAM														
CHF	CIT	Treatment	--	1125	774	21.1 (21.6)	0.0 (0.0)	0.0 (0.0)	0.7 (0.0)	0.4 (0.0)	1.0	± 2.1	p = 0.20	3
CHF	CIT	Control	--	1039	1039	15.7 (16.6)	0.7 (1.9)	0.0 (0.0)	0.3 (0.0)	0.0 (0.0)				3

a CHS = yearling spring chinook salmon, CHF = subyearling fall chinook salmon.

b LIT = ladder injury test, CIT = canal injury test.

c Treatment DD-3 was the control for Treatment UD-1.

d UD-1 = upstream of diffuser D-l, DD-3 = downstream of diffuser D-3, AWG = auxillary water gate (G-3), G-l = high flow fish entrance gate 6-1, G-2 = low flow fish entrance gate G-2.

c Risk of error for rejecting H_o: (T - C) = 0 in favor of alternative H_a: (T - C) > 0.

cuts and bruises inflicted during impingement. When both canal pumps were operating, fry were observed holding along the downstream half of the screen and occasionally bumping into the screen; only one fry was pinned against the screen during pump operation. Approximately six fry were also observed pinned on the inclined screen in the bypass channel after dewatering.

Maxwell Dam and Canal

Canal Injury

The headworks canal and drum screens at Maxwell Canal caused few injuries to subyearling fall chinook salmon that traveled from the headgates to the bypass downwell (Table 7). The difference in mean injury rates of treatment and control fish was not significantly greater than zero ($t = 1.04$, $P = 0.20$). The predominant net change in fish condition between recaptured treatment and control fish was a 0.4% increase in other injuries and mortality. Injuries included bird marks (60%), torn operculums (30%), and cuts or bruises (10%). Mean fork length of test fish was 82.3 mm (Appendix Table C-1).

Recovery and Travel Time

Time to recapture 50% (median travel time) of the fall chinook salmon released near the start of the 1.5-mile-long headworks canal averaged 2.9 hours. Median travel times for day-'(3.6 hours), evening- (2.6 hours), and night-released (2.6 hours) test fish were not significantly different ($F = 2.21$, $P = 0.19$; Table 2). None of the replicate groups attained a 95% recapture by the end of the test; only 78.8% of all treatment fish were recaptured. Mean percent recapture of day-, evening-, and night-released test fish were significantly different ($F = 9.57$, $P = 0.01$). Duncan's multiple range test indicated the mean percent recapture rate for day-released (70.3%) fish was less than either evening- (85.7%) or night-released (80.3%) fish.

Velocity Measurements

Drum Screens: When canal withdrawal was 78% of maximum capacity, approach velocities at the drums screens were not uniform throughout the water column (Table 8). Average approach velocity at 80% of water depth (0.48 fps) was considerably higher than at 20% (0.16 fps) or 50% (0.04 fps) of water depth. Six of nine approach velocities measured at 80% of water depth were greater than 0.4 fps; none were greater than 0.8 fps. Mean approach velocity for Screens 3, 2, and 1 was 0.29 fps, 0.25 fps, and 0.14 fps, respectively.

Average sweep velocity for each screen increased with proximity to the bypass channel. Mean sweep velocity for Screens 3, 2, and 1 was 0.61 fps, 0.86 fps, and 1.10 fps, respectively.

Bypass Channel: Mean approach velocity at the bypass channel entrance was 2.34 fps when canal operations followed normal criteria (Appendix Table A-3). Approach velocity ranged from 2.22 fps near the water surface to 2.49 fps near the bottom (Table 6).

Table 8. Sweep and approach velocities (fps) at the Maxwell Canal drum. screens, Umatilla River, spring 1993. Drum screens are numbered in descending order from upstream to downstream. Canal flow was 39 cfs. Bypass flow was 9 cfs.

Drum screen no.	Transect	Sweep velocity: Percent of water depth 20%	50%	80%	Approach velocity: Percent of water depth 20%	50%	80%
3	Upstream	.26	.47	.52	.31	.41	.53
2	Upstream	.90	1.14	.77	.20	-.18	.51
1	Upstream	1.35	1.40	.51	.22	-.33	.39
3	Middle	.52	.84	.69	.13	.15	.50
2	Middle	.77	1.00	.55	.09	.13	.57
1	Middle	1.19	1.41	.47	.27	-.06	.65
3							
2	Downstream Downstream	.84	1.(.84	.72	.14	.34	.47
1	Downstream	1.39	1.45	.75	-.10	-.15	.37

Feed Canal Dam and Feed Canal

Drum Screen Velocity Measurements

Approach velocities in front of the drum screens at Feed Canal exceeded criteria for salmonid fry (0.4 fps) and fingerlings (0.8 fps) in 80% and 42% of the sampling locations, respectively (Table 9). Mean approach velocities for each screen generally increased with closer proximity to the bypass channel, ranging from 0.53 fps at Screen 3 to 1.18 fps at Screen 10; average approach velocity for all 10 drum screens was 0.73 fps. Approach velocity also varied with depth and upstream-downstream screen transects. Mean approach velocity for all screens at 20%, 60%, and 80% of water depth was 0.61 fps, 0.92 fps, and 0.67 fps, respectively. Mean approach velocity was also higher at upstream transects (0.91 fps) than middle (0.72 fps) or downstream (0.73 fps) transects.

Sweep velocities exceeded 1.0 fps in most locations. Mean sweep velocities progressively increased from Screens 2 through 10, ranging from 0.96 fps to 1.80 fps. Mean sweep velocity for Screen 1 was unusually low (0.27 fps). Sweep velocity was higher near the water surface; mean sweep velocity at 20%, 60%, and 80% of water depth was 1.63 fps, 1.32 fps, and 1.32 fps, respectively.

Bypass Channel Velocity Measurements

Mean approach velocity at the bypass channel entrance was 3.02 fps when the canal headworks elevation was 1 foot below normal operating criteria

(Appendix A). Approach velocity ranged from 2.95 fps near the water surface to 3.06 fps near the bottom (Table 6).

Table 9. Sweep and approach velocities (fps) at the Feed Canal drum screens, Umatilla River, spring 1993. Drum screens are numbered in ascending order from upstream to downstream locations. Canal flow was near standard capacity at 211 cfs. Bypass flow was 18 cfs.

Drum screen no.	Transect	Sweep velocity: Percent of water depth 20%	60%	80%	Approach velocity: Percent of water depth 20%	60%	80%
1	Upstream	-.20	-.33	.05	.67	.84	.75
2	Upstream	1.06	.92	.79	.24	.60	.37
3	Upstream	1.41	1.25	1.23	.51	.86	.70
4	Upstream	1.72	1.42	1.62	.22	1.02	.75
5	Upstream	1.96	1.55	1.49	1.28	1.30	.64
6	Upstream	1.89	1.59	1.60	.91	1.08	.76
7	Upstream	2.05	1.48	1.62	.51	1.36	.86
8	Upstream	2.12	1.55	1.45	.82	1.13	.94
9	Upstream	2.05	1.81	1.88	1.34	1.35	.90
10	Upstream	2.12	1.99	1.93	1.29	1.50	1.72
1	Middle	.64	.33	.25	.53	.53	.52
2	Middle	1.19	.98	.50	.45	.87	.50
3	Middle	1.40	1.06	1.37	.86	.71	-47
4	Middle	1.50	1.42	1.51	.52	.43	.52
5	Middle	1.77	1.54	1.63	.71	1.21	.55
6	Middle	1.80	1.65	1.50	.95	.88	.83
7	Middle	1.84	.92	1.52	.96	1.14	.47
8	Middle	2.00	1.86	1.45	.72	.64	.90
9	Middle	1.97	1.58	1.60	.20	1.21	.63
10	Middle	2.00	1.63	1.72	.22	1.06	1.26
1	Downstream	.67	.48	.55	.48	.62	.35
2	Downstream	1.29	1.06	.84	.38	.98	.47
3	Downstream	1.37	1.38	1.30	.34	.19	.09
4	Downstream	1.67	1.33	1.41	.86	.96	.09
5	Downstream	1.92	1.54	1.53	.46	1.12	.94
6	Downstream	1.96	1.43	1.50	.28	.74	.oo
7	Downstream	2.00	1.72	1.65	.98	.28	.56
8	Downstream	1.92	1.53	1.46	.69	.84	.90
9	Downstream	1.93	1.47	1.29	-1.30	.83	.24
10	Downstream	1.99	1.45	1.35	1.08	1.20	1.27

DISCUSSION

Westland Dam and Canal

Injury

Juvenile chinook salmon were able to safely pass through the Westland Canal bypass facility under the operating conditions tested without incurring significant injury. The low injury rates of test fish are consistent with results of analogous tests at juvenile fish passage facilities in the Umatilla River (Hayes et al. 1992, Cameron and Knapp 1993) and the Yakima River Basin, Washington (Hosey and Associates 1988a, 1988b, 1989, 1990; Neitzel et al. 1985, 1987, 1988, 1990a, 1990b).

Juvenile fish may not experience safe conditions as they are trapped and loaded for transport from the juvenile fish holding pond at Westland Canal. Injury incurred by fish during crowding and net-dipping procedures is a concern. Our findings indicated net-dipping procedures imparted more injury to fish than the crowding procedure. However, the crowding procedure may actually cause a higher amount of injury than we estimated because trap-caused injury was not subtracted out from the control (pond). A study in 1992 (Walters et al. 1994) suggested an association between the amount of time fish are held in the crowded area of the juvenile pond at Westland Canal and injury and subsequent mortality under secondary saltwater stress. Although minimizing stress and injury during handling and loading is difficult, improved procedures should be considered (and more careful handling of salmonids would ensure healthier fish and undoubtedly increase survival). We plan to study the effects of pump-loading procedures on fish condition at Westland Canal in 1994.

Recovery and Travel Time

Good recovery rates are crucial to obtaining reliable data during injury tests. Although very low recovery of headgate injury treatment fish seriously affected the reliability of injury test results, the data obtained suggested that fish passing through open headgates were not seriously injured. Collection efficiency of the downwell trap (99.3%) was not the cause of low recovery rates for the headgate injury treatment fish. Recovery rates of fish released upstream of the headgates appeared to be dependent on river flow and which headgates were open. Low recovery of test fish in the bypass outlet injury test was still adequate for determining the injury rates of recaptured fish, but the condition and fate of more than half the treatment fish (64%) could not be determined. High recovery rates of test fish in the screen injury test (> 95%) increased the reliability of the results and decreased the percentage of fish that were unaccounted for at the end of the test.

The screen facility at Westland Canal does not appear to prolong passage of juvenile salmonids. At least half of the test fish we released moved through the screen facility within 1.5 hours when canal withdrawals were low (57 - 90 cfs) during tests with spring chinook salmon, and when they were high (195 - 267 cfs) during tests with fall chinook salmon. Overall, 95% of the test fish we released moved through the screen facility in less than a day. These rates of fish movement were within the ranges of travel times observed for juvenile chinook salmon at fish bypass facilities on the Yakima River (Hosey and Associates 1988a, 1988b, 1989; Neitzel et al. 1990b, 1991), and generally faster those observed at the WEID Canal juvenile fish bypass facility, Umatilla River (Hayes et al. 1992, Cameron and Knapp 1993).

We could not determine whether fish are returned to the river quickly through the downwell and fish bypass pipe. Low recapture rates of fish during the lower bypass test may have been caused by low capture efficiency of the outlet trap (and) or fish holding in the downwell, bypass pipe, or other portions of the facility drainage system. Outlet trap efficiency, based on the recapture of control fish released directly into the net mouth, can account for only 42% of the treatment fish that were not recovered during the test. However, treatment fish were probably better able to avoid the trap than control fish because they exited the outlet approximately 2 meters in front of the net. Fish were able to access the pumpback bay and overflow drainage system through its connection with the bypass pipe this year when the facility operated at maximum bypass flow. Fish movements in the facility drainage system should be monitored in 1994 after the flap gate has been modified.

Diversion Rate

It appears that only a low'percentage of fish that travel past the headgates during moderate to high river flows (> 400 cfs) are diverted into the Westland Canal. Although the duration of our tests was limited, we observed this pattern of fish diversion on 6 of 7 sampling dates (Appendix Figure C-3). Low diversion rates were observed during both low and high canal withdrawals. Diversion rates may be affected by the hydraulic conditions created by varying configurations of open and closed headgates. We observed the highest amount of fish diversion when only the two downstream headgates were open, but low diversion rates when either one or six headgates were open. The one sampling date when high diversion rates were observed may have been an artifact of fish movements in response to rapidly increasing river flow, turbidity, and debris load.

Drum Screen Efficiency

Based on our tests with fall chinook salmon fry, the overall mean screening efficiency of the rotary drum screens at Westland Canal was high (99.95%). However, some fry leakage was observed at half the screens. Faulty screen seals may have been the cause for fry passage through the screens, because no roll-over was observed during the tests and the mean size (53.5 mm) of fry captured behind the screens was too large to pass through the mesh openings (Fisher 1978). Faulty seals were also thought to be the cause of fish leakage through drum screens during tests conducted at fish bypass facilities on the Yakima River (Neitzel et al. 1988, 1990a). Side seals may be worn from deployment and retrieval of drum screens within screen guides that contain minimal tolerances (Wayne Kowolka, ODFW Engineering, personal communication). Inspection of screen seals will be necessary during each winter maintenance period, with possible replacement.

Fish bypass facility operations were less than ideal for conducting drum screen leakage tests. We preferred to conduct the tests during higher canal withdrawals to more rigorously evaluate the potential for fry passage through or over the screens. However, the timing of these tests was constrained by the availability of test fry (mid-March to early April). The lack of bypass flow and the inability to divert and collect test fry in the bypass channel precluded a precise estimate of the numbers of fish that moved past the screens. We used only the total number of fish released during each test as our estimate of fish encountering the screens. We consider our screen efficiency estimates to be conservative (low) because observations of fry congregating at Drum Screen 10 suggest the numbers of fish that actually encountered the screens was higher than the screen efficiency formula took into account.

Leakage or roll-over of subyearling chinook salmon during the spring outmigration period did not appear to be a serious problem during normal operations. All fish captured in the fyke nets were dead and believed to have been weakened fish that rolled over the screens.

The incidence of roll-over appears to increase with proximity to the bypass channel entrance. A week prior to monitoring, we observed weakened subyearling chinook salmon rolling over Drum Screens 6, 8, 9, and 10. The downstream edge of drum screen 10 appears to be the location where weakened fish are most likely to roll-over. Weakened fish can readily access the bypass channel at this location, but have been observed holding in the small back-eddy created by the bypass channel wall; these fish can become exhausted and roll over the screen (Figure 8).

Traveling Screen Efficiency

Both traveling screens at Westland Canal were 100% efficient for preventing fry leakage into the pumpback bay in the operating mode tested. We conducted the test following passage evaluation operating criteria (Appendix A) for bypass flow (18 cfs to 20 cfs) and passing 3 cfs through each traveling screen. Normally, flow is not drawn through the traveling screens unless the fish bypass facility is operated in a trapping mode. The potential for fry leakage through the screens may be higher during normal trapping operations because sweep velocities in front of the screens are probably much lower (4 cfs bypass flow) than existed during our test conditions. No fry leakage or impingement during test conditions suggests that there is not a gross leakage problem with the screen seals or approach velocities.

Velocity and Flow Measurements

Drum Screens: Water velocities measured in front of the drum screens this year at high canal flow, and in 1992 at moderate canal flow (Cameron and Knapp 1993), did not exceed screening criteria in most sampling locations (NMFS 1989); however, velocities were not uniform. The key locations where approach velocities did not meet design specifications included 80% of water depth, the downstream transect of Screens 8, 9, and 10, and upstream transects of Screens 1 and 10. A higher incidence of fish leakage and roll-over was observed at screens where we measured high approach velocities. Alteration of

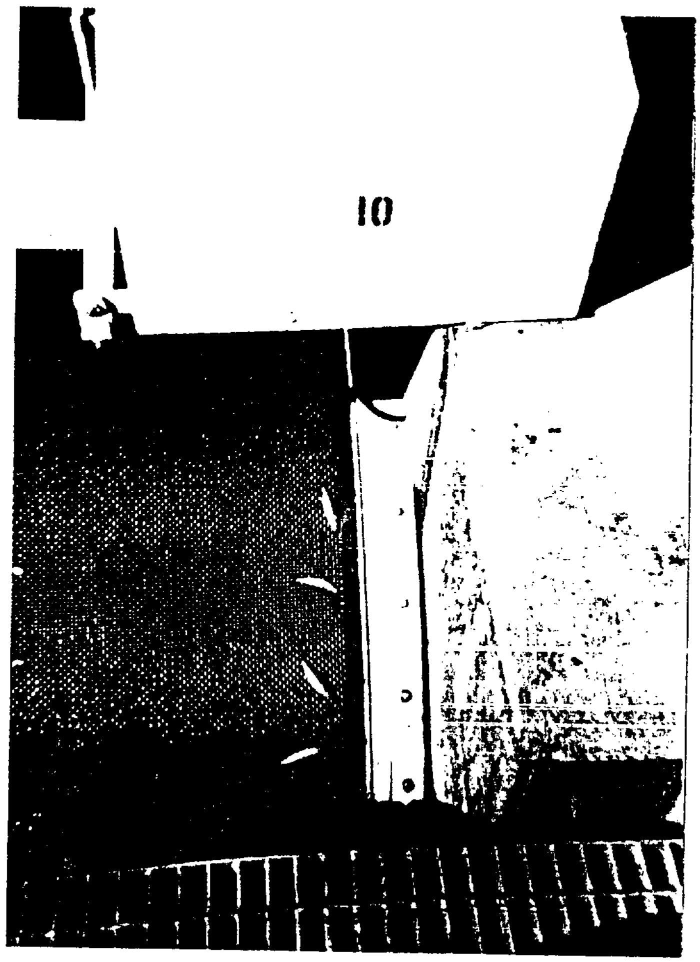


Figure 8. Subyearling chinook salmon pinned and rolling over the downstream edge of Drum Screen 10 at the Westland Canal juvenile fish bypass facility at Westland Dam, Umatilla River, spring 1993.

horizontal baffle board configurations behind the screens may achieve a gross improvement in velocity control and uniformity. However, a vertical louver design would provide finer control. The negative approach velocities are probably a result of water deflection at the screen face where measurements were taken (telephone communication, 16 July 1993, William S. Rainey, NMFS, Portland, Oregon).

Traveling Screens: Water velocity in front of the traveling screens produced by simulated trapping operations is probably representative of actual velocities occurring during normal trapping operations. The high approach velocity at the upstream transect of Screen 1 could possibly be reduced with modified baffling.

Bypass Channel: Travel times and recovery rates of test fish released in the screen facility indicate that water velocity at the bypass channel entrance was sufficient to attract fish when the facility was operated according to revised criteria. However, problems with fish passage were encountered in the lower bypass associated with the relatively high amount of bypass flow (approximately 26 cfs) during these operations. Bypass flow roughly doubled under revised operations compared with previous bypass operation (10 cfs). At high bypass flow, air became entrained in the bypass pipe and was vented at the flap gate box. The venting process may have created a reverse flow through the drain pipe, which drew fish back toward the facility. Fish were observed in the flap gate box and pumpback bay during this period. Reducing bypass flow to 10 cfs shortly thereafter corrected the air entrainment problem, but its effect on fish movements was not quantified. Implementation of new facility operating criteria this year has provided insight into the effect that changes in operation in one area might have on other facility components and fish passage.

Facility Operations

Total or partial occlusion of the mid-channel bypass outlet caused by bedload movements during high river flow was the primary operational problem at the Westland Canal juvenile fish bypass facility. Total occlusion of the outlet shuts down both fish bypassing and trapping operations until remedial removal of gravel is possible. The unstable river channel above and below Westland Dam has created this chronic problem. In 1993, gravel occluded the outlet after high river flows in late March, early April, and early May. Partial occlusion of the outlet also created a fish passage problem as fish exiting the bypass pipe were thrust against gravel deposits.

Several attempts were made to keep the bypass clear of gravel. Instream structures were installed on 20 April 1993 in an attempt to make the bypass outlet self-scouring. The structures consisted of two rows of boulders (approximately 1 cubic yard each) placed at an approximately 45 degree angle to river flow in front of the bypass outlet (Figure 9). The boulder configuration failed when a major flood in early May caused substantial bedload movement, channel changes (Figures 9 and lo), and the disappearance of some of the boulders. The main river channel shifted from the right to left bank as a result of. the flood event.

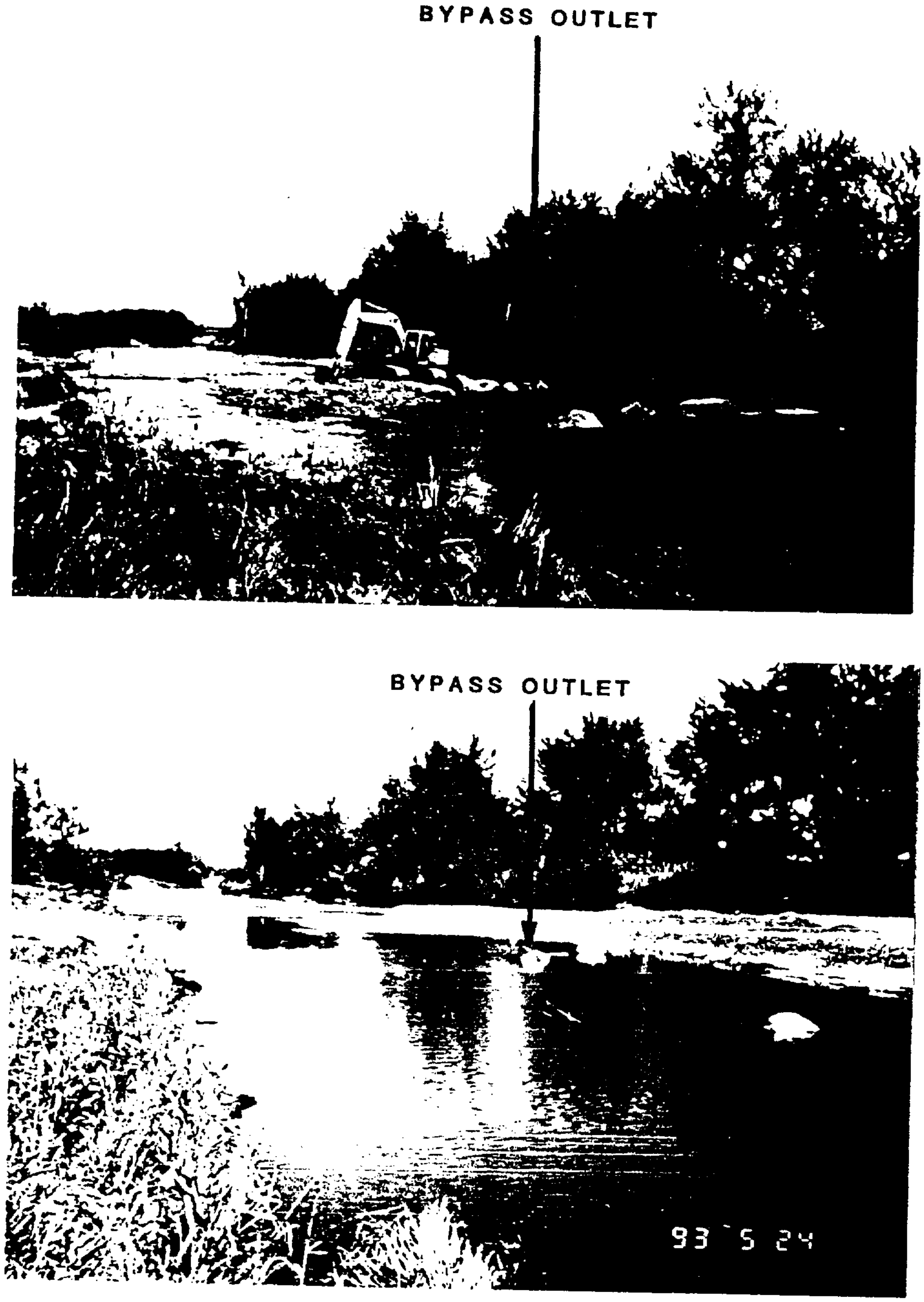


Figure 9. River channel characteristics near the bypass outlet at the Westland Canal juvenile fish bypass facility before (top: 4/20/93) and after (bottom: 5/24/93) a major flood event in early May, Westland Dam, Umatilla River, spring 1993. Photos were taken approximately 50 yards south of the bypass outlet.

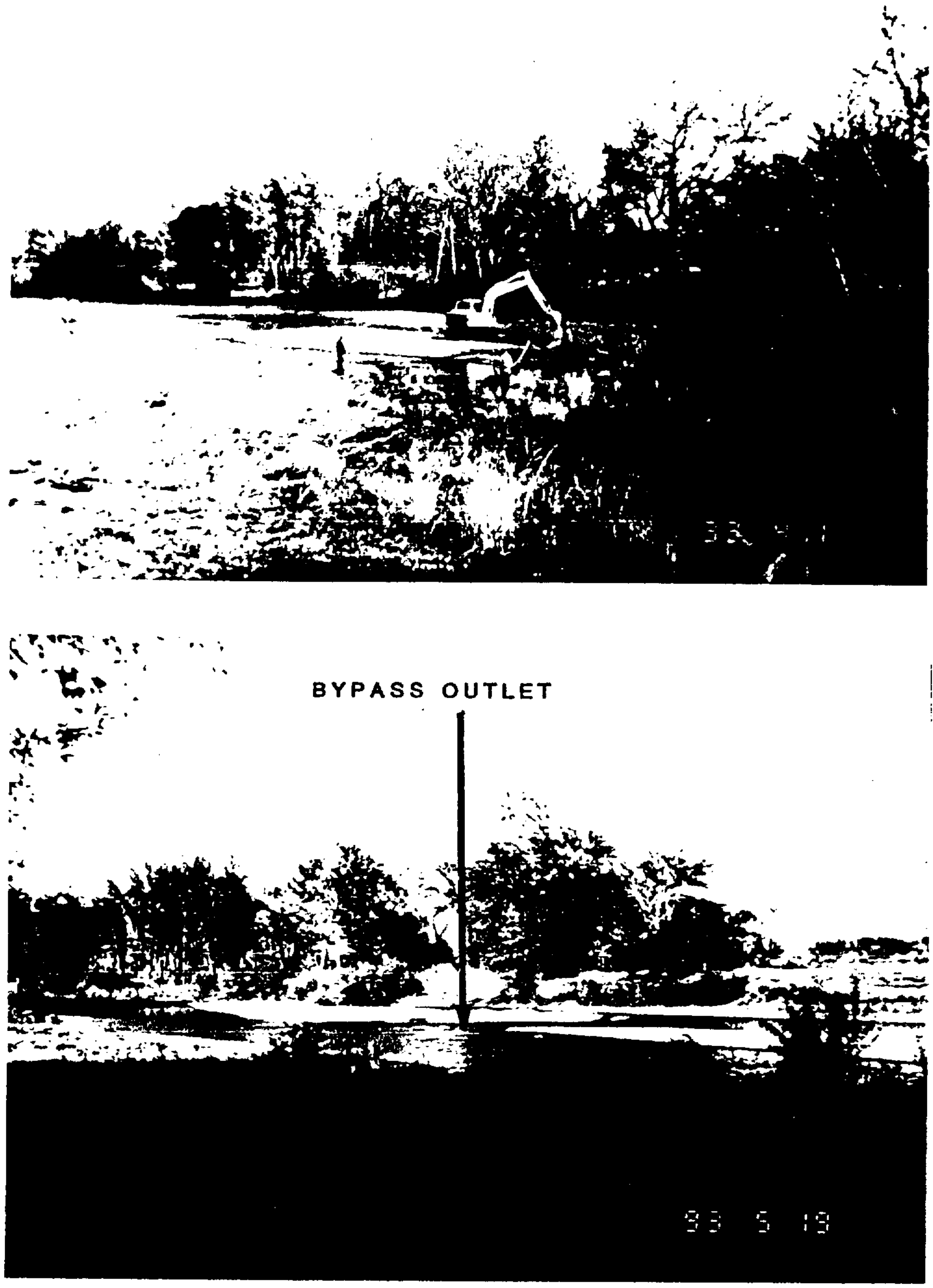


Figure 10. River channel characteristics near the bypass outlet at the Westland Canal juvenile fish bypass facility before (top: 4/14/93) and after (bottom: 5/19/93) a major flood event in early May, Westland Dam, Umatilla River, spring 1993. Photos were taken approximately 30 yards south-west of the bypass outlet (located directed under the backhoe's lifting bucket).

Revision of facility operating criteria was another measure taken this year to deter gravel deposition at the bypass outlet. Revising normal operating criteria from a bypass flow of 10 cfs to maximum bypass flow (approximately 26 cfs).was not effective at preventing gravel deposition at the outlet. The decision to shorten the bypass pipe to the current shoreline will improve access to the outlet for gravel removal operations.

Operating conditions are a significant factor that determine whether impingement and roll-over of juvenile salmonids occurs at the drum screens. For example, an incident of extensive roll-over of subyearling chinook occurred on 26 May 1993 when the bypass was screened and canal withdrawals were high. This situation exemplifies the potential problem for smolt passage when screen velocities are excessive and bypass routes are dysfunctional, and illustrates the complexity of safely moving fish through the river system.

Adult and juvenile chinook salmon have been found in the canal, flap gate box, and pumpback bay at Westland Canal, indicating that fish are able to move back into the facility via the bypass pipe and drainage system. This problem is directly related to facility operation and design and decreasing river flow; fish are attracted to flows from the facility as river conditions deteriorate and the low head differential between river and facility permits entrapment. Potential facility modifications to partially resolve these problems include (1) installing an air vent to the bypass pipe, and (2) installing a pipe to return juvenile fish to the river that is separate from the pumpback bay and fish holding pond drain pipe.

Problems that occur when the facility is operated in a trapping mode have been detailed in trap and haul annual progress reports (URTHP 1990, 1991, and 1992). Aside from fish access to the pumpback bay, the main problems encountered during trapping operations are (1) reduced flow into the fish holding ponds caused by fluctuating headworks elevation, (2) leakage of juvenile fish into the adult pond through the fish separator, (3) poor holding conditions in the adult and juvenile fish ponds caused by solar heating, and (4) intermittent blockage with debris of water inflow screens to the adult holding pond.

Three Mile Falls Dam and WEID Canal

Ladder Injury

Previous concern as to whether the east-bank ladder is designed to pass juvenile salmon in an effective and non-injurious manner (Knapp and Ward 1990) appears well founded. Maintenance personnel from the Bureau of Reclamation and irrigation districts have periodically removed accumulations of smolts from ladder diffuser gratings during cleaning operations (Gary Gray, USBR, personal communication). Although the ladder injury test with yearling spring chinook salmon was inconclusive due to low recovery of test fish, ladder injury tests with subyearling fall chinook salmon provided conclusive and significant results. Downstream movement through the passage portion of the ladder caused notable injury and some mortality to subyearling smolts. Diffuser grates appear to pose the greatest threat to juvenile fish; debris on the grates may exacerbate the problem. Downstream passage through the auxiliary water system does not appear to cause significant amounts of injury to subyearling smolts. Modifying the diffuser design or establishing a stricter cleaning schedule should be considered to improve juvenile passage conditions in the ladder.

Traveling Screen Impingement

Fry impingement on the traveling screen when the river-return drain pipe was 40% open or when both 10-cfs canal pumps were on corroborated water velocity measurements that identified these two pumpback bay operations as having the greatest potential for fish impingement (Cameron and Knapp 1993). Observation of fry movements after release and the reoccurrence of fry impingement on the downstream edge of the screen substantiates the belief that the hydraulics created by the 5-cfs orifice plate are conducive to impingement at these operations (Hayes et al. 1992). Recommendations to reduce bypass entrance flow and flow through the secondary screen through operation of only one pump, and restrict operation of the river-return pipe to short-term sluicing (Hayes et al. 1992, Cameron and Knapp 1993) are appropriate.

Maxwell Dam and Canal

Canal Injury

Passage through the headworks and screen facility at Maxwell Canal caused an insignificant amount of injury to test fish. Although bird predation is a concern, as herons and kingfishers are commonly seen along the banks of the canal headworks, it does not appear that bird predation is a serious problem; a low percentage (0.8 %) of fresh bird marks was recorded on recaptured treatment fish. During spring floods, high water inundated the headworks at Maxwell Canal, necessitating closure of the canal. The potential exists for stranding fish in the canal when dewatering operations are necessary. If possible, operators should maintain a pool in the canal headworks during temporary shutdowns.

Recovery and Travel Time

We found that roughly 80% of the subyearling fall chinook salmon we released near the headgates were returned to the river within 18 hours. A recovery rate of 80%, after sampling intervals of 23 hours to 58 hours for individual release groups, is within the range of recovery rates observed at other fish bypass facilities (Hosey and Associates 1988a, 1988b, 1989; and Neitzel et al. 1991).

Velocity Measurements

Drum Screens: Water velocities measured in front of the drum screens at 78% of maximum canal flow had a flow pattern similar to that observed at the Westland Canal drum screens. At both sites, flow was not uniform between depths and among screens, and approach velocities exceeding criteria at 80% of water depth, may be attributable to similar baffle board configurations. As at Westland Canal, the configuration of baffle boards at Maxwell Canal should be altered.

Bypass Channel: Travel times and recovery rates of test fish released in the headworks canal indicated that water velocity approaching the bypass channel entrance was sufficient to attract fish when the facility was operated according to normal operating criteria (Appendix A). Water velocity was fairly uniform among sampling depths, and was comparable to velocities measured at WEID Canal when bypass flow was 25 cfs (Cameron and Knapp 1993).

Feed Canal Dam and Feed Canal

Drum Screen Velocity Measurements

Past methods of operating the Feed Canal created velocities in front of the drum screens that had a high potential for fish impingement. The canal was operated with a headworks elevation approximately 1.5 feet below normal operating criteria (EL. 656.0) at the time our measurements were taken. At the lowered elevation, water depth in front of the screens was 3 feet and screen submergence was approximately 50%. The decreased amount of screen surface area in contact with canal flow resulted in approach velocities that greatly exceeded screening criteria for fry (0.4 fps) at all 10 screens. Design and (or) operation of the facility should be modified to ensure the canal headworks is maintained at EL. 656.0 during normal operation and screen submergence is at or above 70%.

The pattern of flow through the drum screens at Feed Canal was dissimilar to those observed at Westland and Maxwell canals, even though the configuration of baffle boards is nearly identical among the three sites. When the headworks water level was below normal criteria, we observed a higher flow through the screens at 60% water depth rather than at 80% water depth and flow among screens and screen transects was not even. The greatest potential for fish impingement is currently at the two end screens where sweep velocity is extremely low (Screen 1) and approach velocity is extremely high (Screen 10). Water velocities in front of the drum screens need to be reexamined when the canal headworks is within normal operating criteria. It is probable that there will be a need to reconfigure the baffle boards to even approach velocities when facility operation is revised.

Bypass Channel Velocity Measurements

Water velocity approaching the bypass channel entrance appears adequate for fish attraction. Slightly lower velocities will probably be observed when the canal is operated within normal criteria.

RECOMENDATIONS

1. Operators at all facilities need to adhere to criteria and ensure that facility or inriver activities do not negatively impact fish passage. Operating criteria that is clear, concise, and up-to-date should be provided to all facility operators. Staff gauges should be installed at all critical locations.

2. Reconfigure baffle boards behind drum screens at Westland, Maxwell, and Feed canals to achieve more uniform flow distribution. Drum screen edge and bottom seals at Westland Canal should be inspected annually and replaced if necessary.

3. The gate and seals to the juvenile pond flap gate box at Westland Canal should be inspected. Adjust system flow and modify the gate to prevent fish passage or leakage.

4. The bypass outlet at Westland Canal should be cut back to the current shoreline, the shoreline reinforced to prevent further erosion, and suitable passage conditions maintained at the outlet.

5. Refinements to proper operation of the automated headgates and checkgates at Westland Canal should be completed. Headgates should be kept in the automated mode to prevent large water level fluctuations in the canal forebay.

6. Establish operating criteria for Westland Canal that provides optimum bypass flow to prevent gravel aggradation at the bypass outlet yet prevents air entrapment in the bypass pipe and a high velocity gradient at the bypass channel entrance.

7. Modify the fish separator at Westland Canal to prevent fish leakage into the adult holding pond. Improve handling of juvenile salmonids to reduce stress and injury during loading for transport.

8. Deployment of sampling equipment and operation of the upper bypass weir gate at the WEID facility at Three Mile Falls Dam needs to be made less labor-intensive if future use includes outmigration monitoring.

9. To operate in a 5-cfs bypass mode at WEID Canal, operate only 1 pump or maintain a river-return pipe opening of 20% (5" on gate stem).

10. Redesign diffuser gratings (D-l and D-3) at Three Mile Falls Dam to reduce injury to juvenile salmonids that migrate through the passage portion of the ladder.

11. Operations at Maxwell Canal should attempt to prevent fish stranding in the canal, wastewater channel, or bypass system. If possible, a pool should be maintained in the canal approach during short-term canal shut-downs.

12. Alter operation of the. screening facility at Feed Canal to ensure the canal headworks elevation is maintained within normal criteria for proper screen submergence.

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APPENDIX A

Juvenile Fish Bypass and Adult Fish Passage Facility Operating Criteria

Westland Canal Fish Screens (NMFS 13 April 93)

The following are interim operating criteria for operation of the Westland screens and bypass - non-pumpback mode - during the 1993 juvenile outmigration season. These new operating guidelines supersede previously prepared criteria. Evaluation operating criteria (for the ODFW juvenile passage study) are included. Pumpback mode operating criteria will be forthcoming in the next few weeks.

Normal Operation (No Pumpback): Normal operation will occur when there is enough bypass flow to return fish directly to the river through the bypass pipe. This assumes that stream flows are sufficient to transport fish downriver. See the attached drawing.

1. Operate with the canal water surface immediately upstream of the drum screens at EL. 640.0 - EL. 640.2 (2.4' - 2.6' below the concrete deck at the drum screens). (The USBR will install a staff gage to allow direct canal water surface readings in the near future.)

2. Slotted weir inserts (closure plates) are to be closed. This blocks flow through the secondary screens and to the pumpwell.

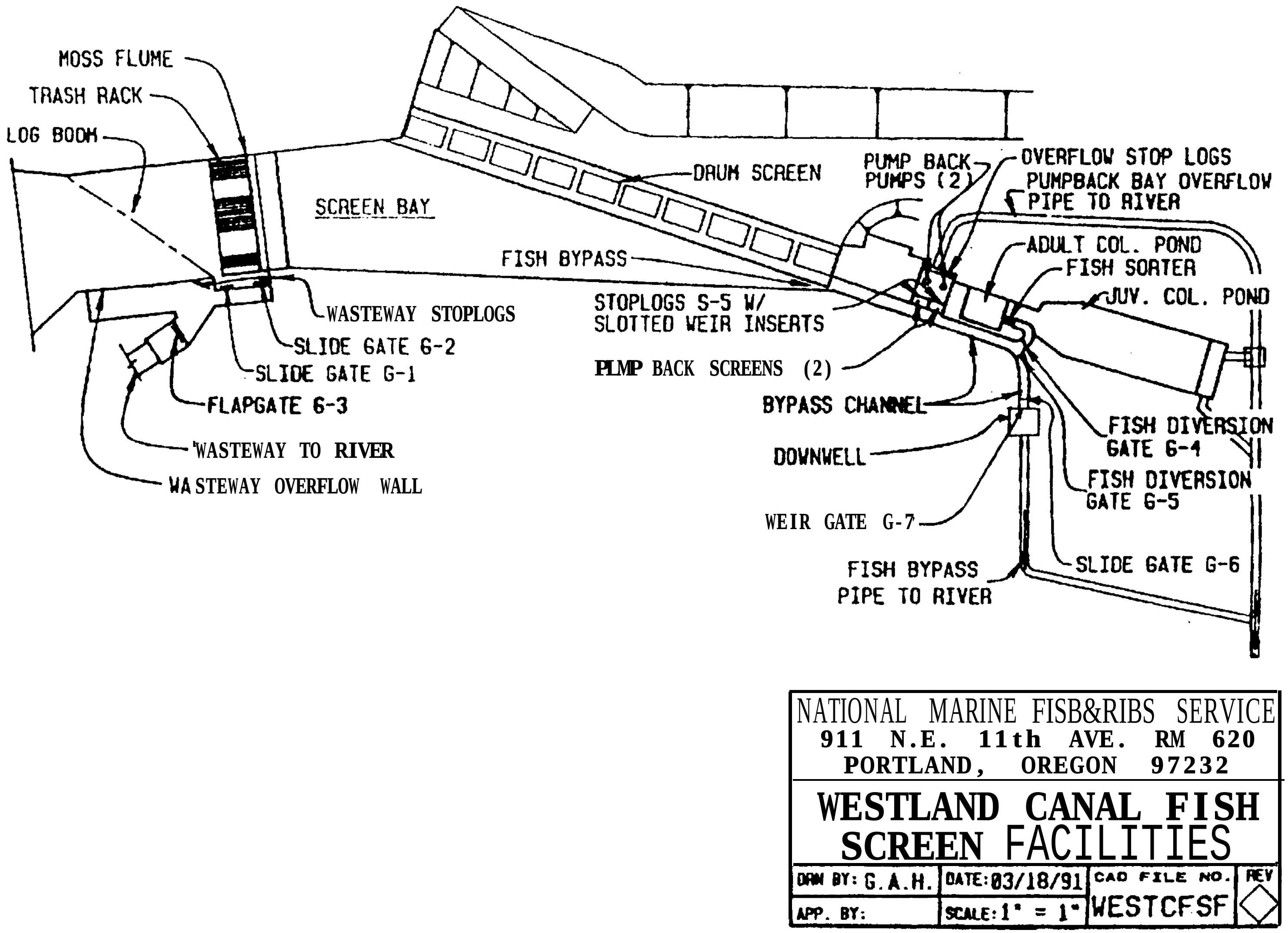
3. Close fish diversion gate G-4.

4. Open fish diversion gate G-5 (full open).

5. Open downwell slide gate G-6 (full open).

6. Lower downwell weir gate G-7 (full down).

[Note: Preliminary computations suggest the above operation will route approximately 15 cfs directly through the bypass downwell and bypass pipe to the river at a river flow of 2000 cfs. As the river recedes to approximately 500 cfs, bypass flow will increase to slightly over 20 cfs. These computations assume negligible flow through the flapgate structure and juvenile pond drain. To the extent that flow through the flap gate (toward the river) increases, bypass flow through the downwell structure will be reduced at the same rate. For example, if flow through the flap gate is 4 cfs, bypass flow will reduced by approximately 4 cfs. CAUTION!! It is probable that the above operation will cause backflow into the pumpwell and adult and juvenile holding ponds until the Bureau of Reclamation can reduce leakage through the seals of the seated flapgate.]



Appendix Figure A-1. Schematic of the Westland Canal juvenile fish bypass facility at Westland Dam, Umatilla River.

Juvenile Evaluation Bypass Operation: When ODFW commences juvenile passage evaluations, there will potentially be a need to reduce bypass flow to allow the bypass downwell structure water surface to be lowered enough to bleed bypass flow through the evaluation screen, and route juvenile fish into the live box. This should amount to lowering the water surface in the downwell approximately 1'. This should be accomplished in the following manner:

1. Gate G-4 is closed.

2. Gate G-5 is fully open.

3. Gate G-6 is fully open.

4. Gradually raise the Gate G-7 weir crest until the downwell water surface drops sufficiently to allow appropriate placement of the evaluation screen, relative to the downwell water surface.

5. After 5 minutes of constant downwell water surface reading (equilibrium has been reached), open slotted weir closure plates incrementally (at 5 minute intervals) to increase flow through the secondary screens and (ultimately) into the lower bypass pipeline system. If closure plate opened excessively, the downwell structure water surface will rise. closure plates only enough to maintain the downwell structure water surface.

Once the evaluation has been concluded, revert to the normal operation by closing slotted weir closure plates.

[Note: There has been difficulty keeping the bypass outfall open due to high flows and gravel accumulations. This can be avoided by maintaining enough flow through the bypass pipeline. When changing from the normal to evaluation mode (or back), be mindful that the problem is especially sensitive during bypass flow reductions at high river flows. Minimize reduced bypass flow periods during periods of high river flow.]

Three Mile Falls Dam (East-bank) Adult Passage Facility (NHFS 9 Hay 89)

[Note: This fishway can be operated in the trapping mode (where adult fish are routed through the steeppass fishway into holding facilities), or passage mode {where fish are allowed to move unimpeded through the fishway).]

Trapping mode: To initiate trapping operations, lower Diffuser D-l and initiate the steeppass pump operation. Insure that flow through the holding facility is adequate. (Operating criteria for the trapping facility to be provided by others.)

Passage mode: To convert to the passage mode, insure that no fish remain in the adult holding pool, then shutdown the steeppass pump and lift D-l.

Trashrack and diffuser maintenance: Inspect and clean as necessary the trapping diffuser (D-1), entrance pool diffusers (D-2), counting window crowder diffuser (D-3), and fishway exit trashrack (T-1) so the head differential across each diffuser or rack is 0.2 foot or less. Inspect and clean as necessary the auxiliary water trashracks (T-2) so the differential across the racks is 0.5 foot or less.

Steeppass pump screen: Inspect and clean as necessary so the head differential across the screens does not exceed 0.5 foot. (This pump only operates during trapping,)

Keep the counting and crowder windows clean. (Brushing this on a daily basis is much easier than letting aquatic growth accumulate, then trying to clean.) Keep staff gages clean and readable.

Entrance gate operation:

1. Entrance Gate G-1 should be open during all times that flow past the dam does not exceed 1600 cfs (forebay elevation 405.2). Entrance Gate G-2 should be closed during this period.

2. During periods when flow past the dam is expected to exceed 1600 cfs (EL. 405.2) for more than a few days,, entrance Gate G-2 should be open. Entrance Gate G-1 should be closed during this period.

3. After raking racks, adjust auxiliary water control gate G-3 as necessary to achieve head differential at the entrance of 1.0-1.5 feet, relative to tailwater.

Maxwell Canal Fish Screens (NHFS 15 February 1990)

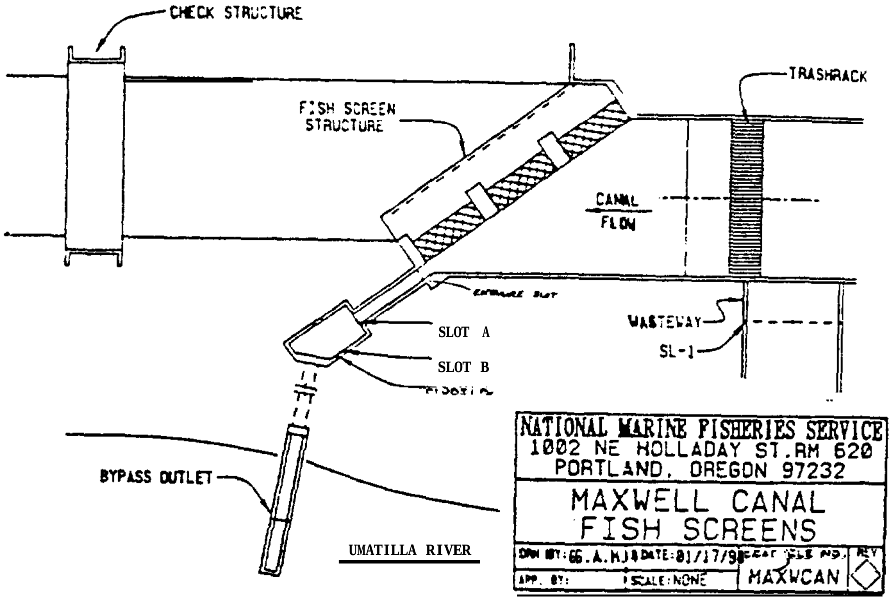
Normal Operation: Set slide gate at check structure downstream of screens to provide a water surface elevation of 526.9 at the screens. The canal water surface should not exceed or fall below elevations 526.7 and 527.1 (70% and 80% screen submergence).

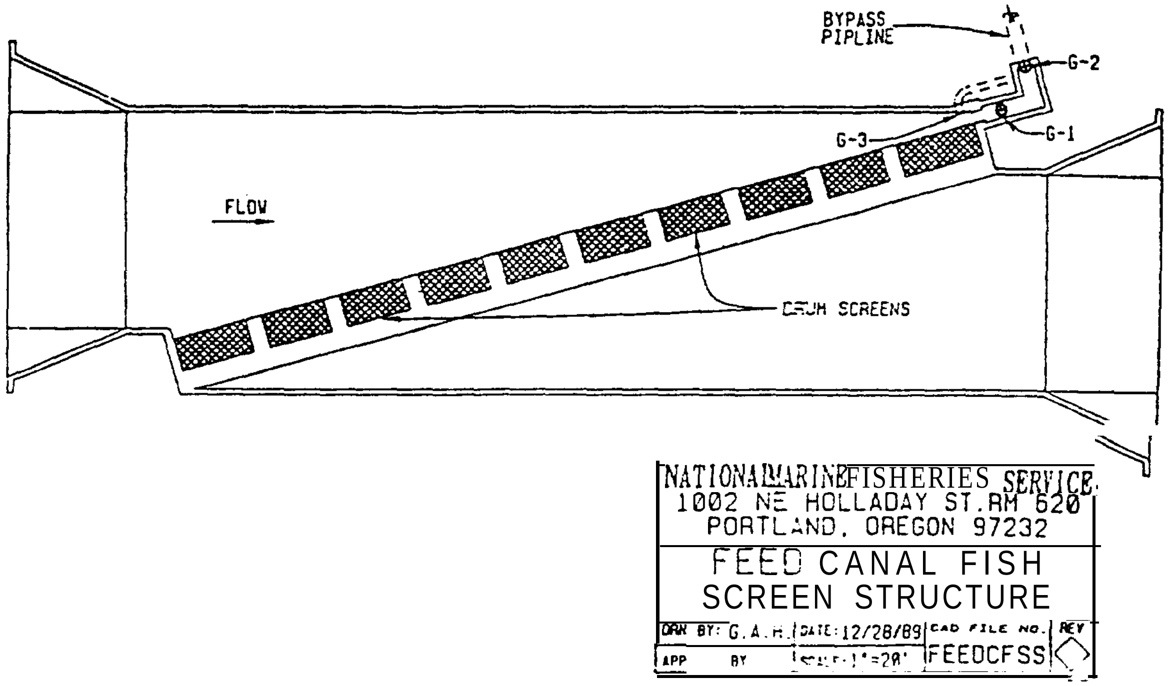
Set wasteway stoplogs, SL-1, at elevation 526.7, which is 0.5 ft. above the wasteway invert elevation.

Clean trashracks to maintain a head differential of 0.3 ft. or less.

Slots C and B are to remain empty. Slot A should be installed to provide 1.5 ft. of bypass weir head (measured from top of stoplog to upstream water surface). The maximum allowable head is 2.0 ft. and the minimum head should be 1.25 ft.

Low Bypass Operation: (During the spring juvenile outmigration months only). When the river flow downstream of the diversion dam is near zero, reduce the bypass weir head at Slot A to 0.5 ft.





Appendix Figure A-2. Schematic of the Maxwell Canal and Feed Canal juvenile fish bypass facilities at Maxwell Dam and Feed Canal Dam, Umatilla River.

Zero Bypass Flow Operation: (During the summer months). When river flow downstream of the diversion dam drops to zero, reduce the bypass flow to zero.

Feed Canal Fish Screens (NHFS 26 February 1990)

General:

1. Gate G-2 is a closure gate only, and should be open when fish are to be passed.

2. Gate G-3 is used only to drain canal, and should be closed during normal operations. (Residual juveniles holding upstream of screens can be released back to the river through G-3.)

Low Streamflow Operation (no spill):

1. Set head gates and structure gates to maintain canal water surface at EL. 656.0. Canal water surface should not fall below or exceed elevations 655.4 and 656.5 (70% to 90% screen submergence).

2. Set bypass Gate G-l at 0.7 ft, below canal water surface.

Normal Operation (spill):

1. Set head gates and check structure gates to maintain canal water surface at EL. 656.0. Canal water surface should not fall below or exceed elevations 655.4 and 656.5 (70% to 90% screen submergence).

2. Set bypass Gate G-l at 1.5 ft. below canal water surface.

High Water Operation (forebay elevation more than 657.3):

1. Set head gates and check structure gates to maintain canal water surface at EL. 656.5 (90% submergence).

2. Lower bypass Gate G-l to its lowest position.

[Note: If canal water surface is not at or near 90% submergence during high flow periods, bypass flow direction may be reversed.]

APPENDIX B

Experimental Design and Test Fish Releases

Appendix Table B-l. Experimental design of tests conducted at Westland, WEID, and Maxwell canal juvenile fish passage facilities and the (east-bank) adult fish passage facility at Three Mile Falls Dam , Umatilla River, spring 1993.

Test[a]	No. tests	T/C[b]	Release dates	Groups per date	No. fish per group	Total no.. fish per species	Species[c]
WESTLAND CANAL JUVENILE FISH BYPASS FACILITY							
DSL	1	Thw	3	2	500	3,000	CHF fry
DSL	1	Cfn	3	10	100	3,000	CHF fry
TSL	1	Tbc	2	3	200	1,200	CHF fry
TSL	:	Cbc	2	3	100	600	CHF fry
TSL		Cfn	2	2	150	600	CHF fry
HIT	1	T	3	3	150	1,350	CHS
HIT	1	T	1	3	150	450	CHF
HIT	1	T	2	1	150	300	CHF
SIT	:	T	3	3	150	1,350	CHS
SIT		C	3	3	150	1,350	CHS
SIT	:	T	1	3	150	450	CHF
SIT			1	3	150	450	CHF
SIT	1	i	2	2	150	600	CHF
SIT	1	C	2	3	150	900	CHF
BOIT	1	T	3	3	150	1,350	CHS, CHF
BOIT	1	C	3	3	150	1,350	CHS, CHF
T&H	1	Tdn	3	3	100	900	CHS/F
T&H	1	TC	3	3	100	900	CHS/F
T&H	1	CC	3	3	100	900	CHS/F

[a] DSL = drum screen leakage test, TSL = traveling screen leakage test, HIT = headgate injury test, SIT = screen injury test, BOIT = bypass outlet injury test, T&H = trap and haul evaluation.
[b] T = Treatment, C = Control, hw = headworks, fn = fyke net, bc = bypass channel, dn = dip-net, c =crowd.
[c] CHF = fa77 chinook saLmon CHS = spring chinook salmon, CHS/F = spring and fa77 chinook salmon.

Appendix Table B-l. (Continued)

Test[a]	No. tests	T/C[b]	Release dates	Groups per date	No. fish per group	Total no. fish per species	Species
WEID CANAL JUVENILE FISH BYPASS FACILITY							
TSI	6	T	2	4	100	4,800	CHF fry
TSI	6	Cbc	2	1	100	1,200	CHF fry
THREE MILE FALLS DAM (EAST-BANK) ADULT FISH PASSAGE FACILITY							
LIT	1	Tud-1	1	3	150	900	CHS
LIT	1	Taw	1	3	150	900	CHS
LIT	1	Cfn	1	3	150	900	CHS
LIT	1	Tud-1	1	2	150	600	CHF
LIT	1	Tdd-3	1	2	150	600	CHF
LIT	1	Taw	1	2	150	600	CHF
LIT	1	Cfn	1	2	150	600	CHF
LIT	1	Tud-1	1	3	150	900	CHF
LIT	1	Tdd-3	1	3	150	900	CHF
LIT	1	Taw	1	3	150	900	CHF
LIT	1	Cfn	1	3	150	900	CHF
MAXWELL CANAL JUVENILE FISH BYPASS FACILITY							
CIT	1	T	3	3	150	1,350	CHF
CIT	1	C	3	3	150	1,350	CHF

a TSI = traveling screen impingement tests, LIT = 7adder injury test, CIT = canal injury test.

b ud-1 = upstream of diffuser D-1, dd-3 = downstream of diffuser D-l, aw =auxiliary water system.

Appendix Table B-2. Schedule of test fish releases for 1993 evaluations at the Westland, WEID, and Maxwell Canal juvenile fish bypass facilities and the (east-bank) adult fish passage facility at Three Mile Falls Dam, Umatilla River.

Species[a]	Test[b]	Dates	Release no.	Release time	Canal flow (cfs)
WESTLAND CANAL JUVENILE FISH BYPASS FACILITY					
CHF fry	DSL	3/29, 3/31, 4/2	1	0728 - 0915	41 - 51
		3/29 3/31, 4/2	2	1525 - 1700	
CHF fry	TSL	4/27 4/29	1-3	1032 - 1723	--
CHS	HIT and SIT	4/15, 4/16, 4/17	1-3	0935 - 1637	57 - 90
CHS	BOIT	4/23 4/24, 4/25	1 - 3	1100 - 1511	
CHF	HIT and SIT	5/3	1-3	1204 - 1550	195
CHF	HIT	5/19, 5/20	1	0933 - 1655	260 - 267
CHF	SIT	5/19, 5/20	1-2	0926 - 1825	260 -267
WEID CANAL JUVENILE FISH BYPASS FACILITY					
CHF fry	TSI	4/7 to 4/14	1-8	0930 - 1810	
MAXWELL CANAL JUVENILE FISH BYPASS FACILITY					
CHF	CIT	5/12	1-3	1214 - 1715	29
		5/13	1-3	0108 - 0400	22
		5/13	1-3	1804 - 2240	22
THREE MILE FALLS DAM (EAST-BANK) ADULT PASSAGE FACILITY					
CHS	LIT	4/29	1-3	1507 - 1641	--
CHF	LIT	5/17	1-2	1715 - 1808	--
CHF	LIT	5/18	1-3	1459 - 1749	--

[a] CHF = fall chinook salmon, CHS = spring chinook salmon.
[b] DSL = drum screen leakage test, TSL = traveling screen leakage test, HIT = headgate injury test, SIT = screen injury test, BOIT = bypass outlet injury test, TSI = traveling screen impingement test, CIT = canal injury test.

Appendix Table B-3. Hatchery transfer and research liberation information for hatchery-reared test fish used during the juvenile fish passage evaluation, Umatilla River, 1993.

TRANSFERS

Species	Lot	Hatch	Pond	Stock	Slip #	Date	#Rec'd	#/lb	Mark /%
CHF	9592	UM	02A	URB	84556	3/25/93	8,460	235.0	None (in field: RV clip/100%)
CHF	9592	UM	02A	URB	84562	4/05/93	4,590	181.0	" "
CHF	9592	UM	02A	URB	84563	4/09/93	2,093	161.0	" "
CHS	7591	Carson	38	Carson	71466	4/09/93	13,144	21.2	AD/33
CHF	9592	UM	M2C	URB	84568	4/20/93	8,352	96.0	RV/100
CHF	9592	UM	03B	URB	84569	5/10/93	2,700	75.0	RV/100
CHF	9592	UM	03B	URB	84570	5/17/93	1,200	70.6	RV/100
CHF	9592	UM	03B	URB	84571	5/17/93	2,400	70.6	RV/100
CHF	9592	UM	03B	URB	84572	5/19/93	1,836	70.6	RV/100

LIBERATIONS

Species	Lot	Hatch	Pond	Stock	Mark/%	Rel Date	(live) # Rel	#/lb	lbs. Rel	Slip #	Rel Loc. (a)	Morts
CHF	9592	UM	02A	URB	RV100	3/29/93	1,775	235.1	7.55	86245	RM 27.3	218
CHF	9592	UM	02A	URB	RV100	3/31/93	1,910	234.9	8.13	86246	RM 27.3	102
CHF	9592	UM	02A	URB	RV100	4/02/93	1,785	234.9	7.60	86247	RM 27.3	208
CHF	9592	UM	02A	URB	RV100	4/07/93	500	181.0	2.76	72301	RM 3.01	0
CHF	9592	UM	02A	URB	RV100	4/08/93	1,077	181.0	5.95	72302	RM 3.0_1	133
CHF	9592	UM	02A	URB	RV100	4/09/93	994	181.0	5.49	72303	RM 3.01	7
CHF	9592	UM	02A	URB	RV100	4/10/93	1,175	181.0	6.49	72304	RM 3.01	18
CHF	9592	UM	02A	URB	RV100	4/11/93	1,199	181.1	6.62	72305	RM 3.01	4
CHF	9592		02A	URB	RV100	4/13193	600	181.2	3.31	72306	RM 3.0_1	0
CHF	9592	UM	02A	URB	RV100	4/14/93	1,567	180.9	8.66	72307	RM 3.01	39
CHF	9592	UM	02A	URB	RV100	4/27/93	1,396	161.0	0.67	72311	RM27.3	5
CHF	9592	UM	02A	URB	RV100	4/29/93	1.180	161.0	7.33	72312	RM 27.3	0
CHF	9592	UM	M2C	URB	RV100	5/03/93	1,378	90.4	14.00	72317	RM 27.3	0
CHF	9592	UM	M2C	URB	RV100	5/07/93	5,111	98.4	51.94	72318	RM 0	154
CHF	9592	UM	03B	URB	RV100	5/12/93	059	95.6	8.99	72319	RM 14.8	18
CHF	9592	UM	038	URB	RV100	5/13/93	1,716	95.5	17.97	72320	RM 14.8	15
CHF	9592	UM	038	URB	RV100	5/17/93	1,190	70.0	17.00	72321	RM 3.02	26
CHF	9592	UM	03B	URB	RV100	5/18/93	2,491	70.1	35.54	72322	RM 3.02	37

a RM 27.3 = Westland Dam Juvenile Fish Bypass,
RM 3.01 = WEID Canal Juvenile Fish Bypass,
RM 3.0_2 = Three Mile Falls Dam east-bank ladder,
RM 14.8 = Maxwell Dam Juvenile Fish Bypass,
RM 0 = Mouth of Umatilla River.

Appendix Table B-3. (Continued)

Species	Lot	Hatch	Pond	Stock	Mark/%	Rel Date	(live) # Rel	#/lb	lbs. Rel	Slip #	Rel Loc. (a)	Morts
CHS	7591	Carson	38	Carson	AD/33	4/24/93	067	20.0	43.35	72309	RM 27.3	55
CHS	7591	Carson	38	Carson	AD/33	4/24/93	7 5	20.0	3.75	72316	RM 27.3	47
CHS	7591	Carson	38	Carson	AD/33	4/25/93	905	20.0	45.25	72310	RM 27.3	0
CHS	7591	Carson	30	Carson	AD/33	4/28/93	2,604	20.0	134.20	72315	RM 27.3	257
CHS	7591	Carson	38	Carson	AD/33	4/29/93	1,626	20.0	81.30	72313	RM 3.02	320
CHF	9592	UM	03B	URB	RV100	5/19/93	882	70.1	12.58	72323	RM 27.3	33
CHF	9592	UM	03B	URB	RV100	5/20/93	896	68.9	13.00	72324	RM 27.3	0
CHS	7591	Carson	38	Carson	AD/33	4/15/93	1,161	21.2	55.70	86248	RM 27.3	455
CHS	7591	Carson	38	Carson	AD/33	4/16/93	1,304	21.2	61.51	86249	RM 27.3	46
CHS	7591	Carson	38	Carson	AD/33	4/17/93	1,346	21.2	63.50	86250	RM 27.3	86
CHS	7591	Carson	38	Carson	AD/33	4/22/93	50	20.0	2.50	72314	RM 27.3	398
CHS	7591	Carson	38	Carson	AD/33	4/23/93	914	20.0	45.70	72300	RM 27.3	104

APPENDIX C

Ancillary Information from Juvenile Fish Passage Studies

Appendix Table C-l. Mean fork length (mm) and origin of test fish used in injury evaluations at the Westland, WEID, and Maxwell Canal juvenile fish bypass facilities and Three Mile Falls Dam (east-bank) adult fish passage facility, Umatilla River, spring 1993.

Species[a]	Test[b]	Mean fork length (mm)	Standard deviation	n	Origin
WESTLAND CANAL JUVENILE FISH BYPASS FACILITY					
CHF fry	DSL	56.6	3.5	300	Umatilla Hatchery, OR
CHF fry	TSL	62.7	5.6	208	Umatilla Hatchery, OR
CHF	HIT + SIT	73.3	6.4	119	Umatilla Hatchery, OR
CHS	HIT t SIT	124.3	8.8	300	Carson NFH, WA
CHS	BOIT	127.4	8.0	300	Carson NFH, WA
CHS/F	T&H	98.7	6.7	900	Umatilla Hatchery, OR
WEID CANAL JUVENILE FISH BYPASS FACILITY					
CHF fry	TSI	60.9	5.6	300	Umatilla Hatchery, OR
THREE MILE FALLS DAM (EAST-BANK) ADULT FISH PASSAGE FACILITY					
CHF	LIT	82.3	4.9	100	Umatilla Hatchery, OR
CHS	LIT	128.3	7.2	120	Carson NFH, WA
MAXWELL CANAL JUVENILE FISH BYPASS FACILITY					
CHF	CIT	82.3	4.9	300	Umatilla Hatchery, OR

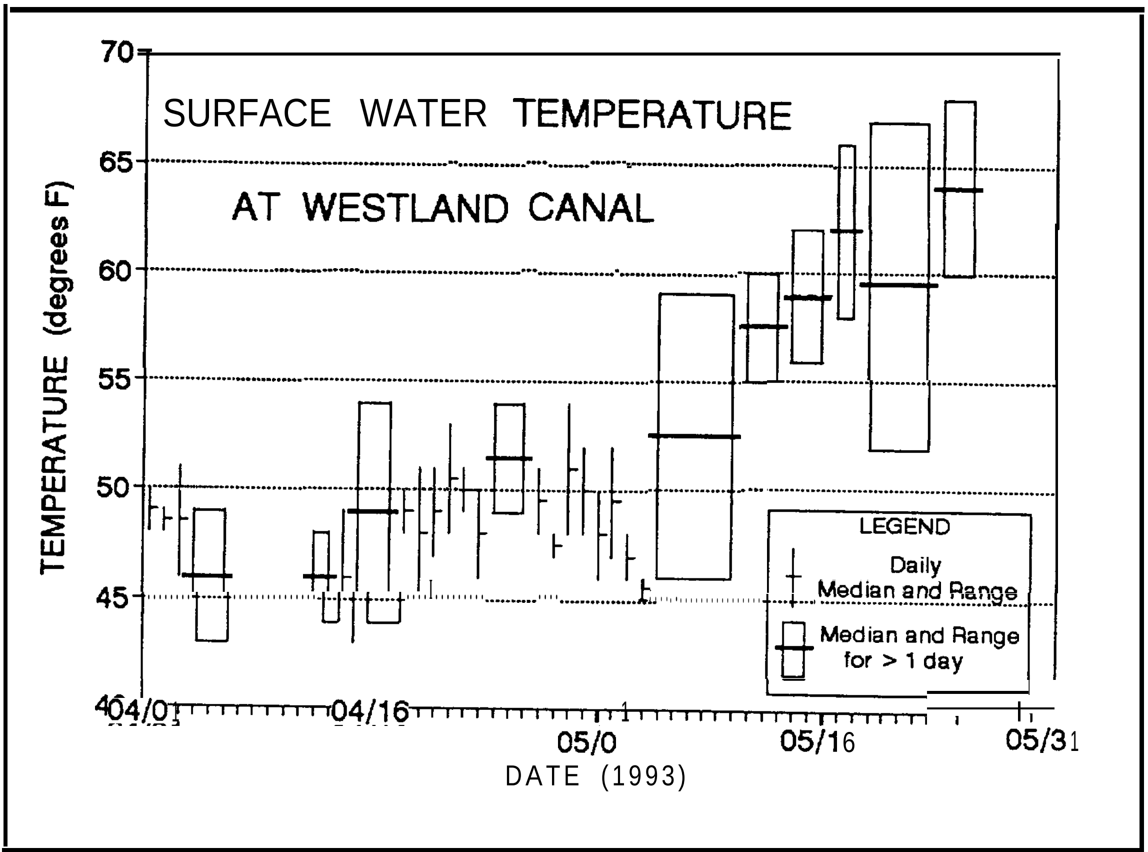
[a] CHF = fa77 chinook salmon, CHS = spring chinook salmon, CHS/F = spring and fa77 chinook salmon.
[b] DSL = drum screen 7eakage test, TSL = traveling screen 7eakage test, HIT = headgate injury test, SIT = screen injury test, BOIT = bypass outlet injury test, T&H = trap and hauL injury evaluation, TSI = traveling screen impingement test, LIT = 7adder injury test, CIT = canal injury test.

Appendix Table C-2. Numbers of river-run juvenile salmonids recaptured while conducting juvenile fish passage tests at the Westland, WEID, and Maxwell Canal juvenile fish bypass facilities and Three Mile Falls Dam (east-bank) adult fish passage facility, Umatilla River, spring 1993.

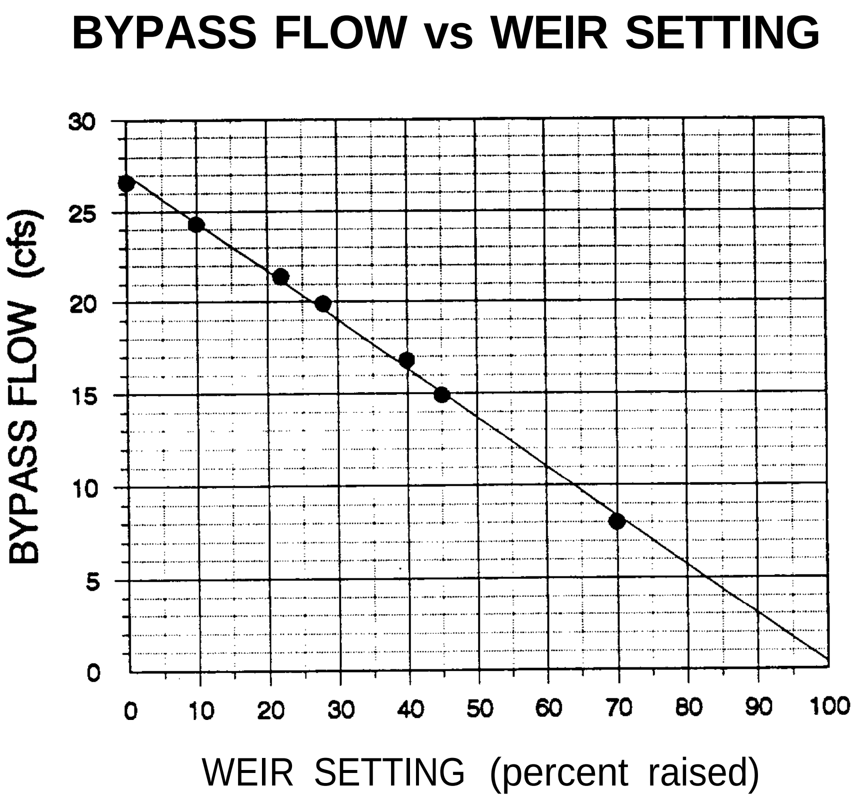
		Trap[a]	Hatchery Fish[b]				Wild Fish[b]				
Date	Time	site	STS	CH-1	Coho	CH-0	STS	CH-1	Coho	CH-0	Fry
WESTLANO CANAL JUVENILE FISH BYPASS FACILITY											
3/29	1000-2120	DW	0	0	8	0	2	0	0	0	0
			1	1	1	2		0	0	2	0
4/15	[illegible]	DW	0	0	5	2	[illegible]	0	0	2	0
			2		6	0	1	0	0	0	0
4/17	[illegible]	DW	6	[illegible]	13		3	0	0	0	0
4/19	0030-1355	DW		2	3	8	0	0	0	0	
4/23	1300-1623	BO	0	0	0	0	0	0	0	0	8
4/24	1320-1500	BO	0	0	0	0	0	0	0	0	0
4/25	1150-1415	BO	0	1	0	0	0	0	0		0
4/27	1600-1800	DW	1	0	2		0		0	8	0
4/29	1130-1320	DW	0	30	0	0	0	8	0	0	0
5/03	1300-2300	DW	31		125	0	34	0	0	0	0
			1		1		1	0	0	0	0
5/19	[illegible]	DW	12	0	1	8	1	0	1	0	0
5/21	0100-1050	DW		0	35	0	36	0	1	0	1
WEID CANAL JUVENILE FISH BYPASS FACILITY											
				2							
4/07	1550-1830	ST	0	12	0	0	17	0	0	0	0
4/08	1155-1800	ST	0		0	0	12	0	0	0	0
4/09	1300-1855	ST	8	[illegible]	818	0		0	0	0	3
4/10	1300-1945	ST		2	245	0	[illegible]	0	0	0	0
4/11	1010-1650	ST	0		13	0	0	0	0	0	0
					5		2	0	0	0	
4/13	[illegible]	ST	0	[illegible]	11	0	7	0	0	0	8
MAXWELL CANAL JUVENILE FISH BYPASS FACILITY											
5/12	1430-2227	DW	0	0	0	0	0	0	0		0
5/13	0007-2320	DW	0	1	2	1	0	0	0	8	0
5/14	0052-2155	DW	0	2	3	0	1	0	0	0	0
THREE MILE FALLS DAM (EAST-BANK) ADULT FISH PASSAGE FACILITY											
4/29	1605-1754	G-2	6	0	4	0	1	0	0	0	0
5/17	1730-1905	G-l	36	0	12	0	0	0	0	0	0
5/18	1550-1940	G-l		0	43	0	13	0	0	0	0

[a] DW = downwell trap, BO = bypass outlet, ST = sampling tank, G-2 = low flow fish entrance gate, G-l = high flow fish entrance gate.

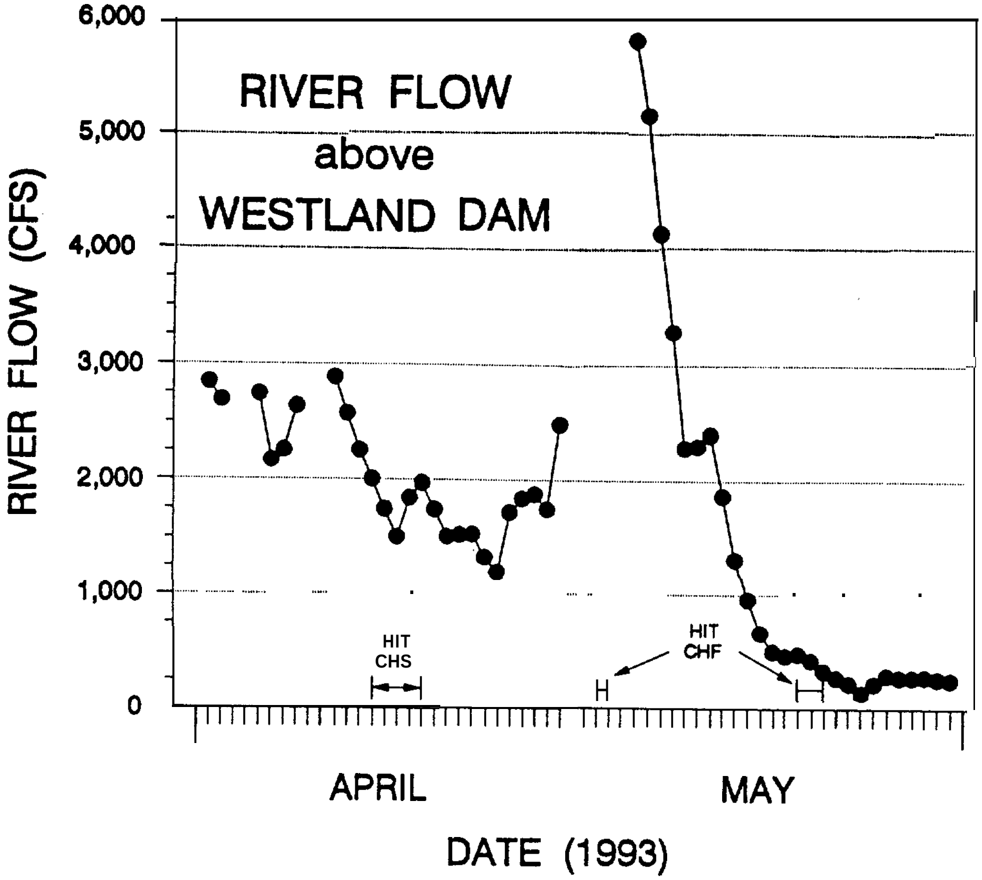
[b] STS = summer steelhead, CH-1 = yearling chinook salmon, CH-0 = subyearling chinook salmon.



Appendix Figure C-1. Median and range of water temperature (°F) recorded at a depth of 0.5 meters in the headworks of the Westland Canal at Westland Dam, Umatilla River, spring 1993.



Appendix Figure C-2. Bypass flow in cubic feet per second (cfs) calculated at varying downwell weir settings at the Westland Canal juvenile fish bypass facility at Westland Dam, Umatilla River, spring 1993.



Appendix Figure C-3. River flow in cubic feet per second (cfs) recorded at the USBR gauging station UMUO located between Westland and Stanfield dams Umatilla River, spring 1993. Time periods when headgate injury tests (HIT) were conducted with spring chinook (CHS) and fall chinook (CHF) salmon are delineated.

Report B

Evaluation of Adult Passage Facilities at Water Diversions in the Umatilla River

Prepared By:
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Confederated Tribes of the Umatilla Indian Reservation

CONTENTS

ABSTRACT

A study of the upstream migration and homing needs of adult salmonids in the Umatilla River was conducted during the 1992-93 return years. Radio telemetry was used to determine the ability of salmonids to successfully negotiate five diversion dam areas on the lower Umatilla River. Transmitters were placed in 13 summer steelhead (Oncorhvnchus mykiss) and 10 spring chinook salmon (Oncorhvnchus tshawvtscha) at Three Mile Falls Dam and fish were monitored as they progressed upstream. A total of eight (61%) summer steelhead and seven (70%) spring chinook salmon successfully negotiated all five diversion dams. Travel time through the diversion areas (days needed to migrate from Three Mile Falls Dam to Stanfield Dam) was on average less for spring chinook salmon than that observed for summer steelhead. Average time required for summer steelhead was 30 days while spring chinook salmon needed on average 11 days to complete the distance. Migration past dams was relatively constant although some delay was documented below Feed Canal Dam and Westland Dam.

The Three Mile Falls Dam west-bank fish ladder was operated for five days in April, 1993 to evaluate adult migration and gain system operational experience. A total of 130 summer steelhead were captured during the study of which 17 (13%) were captured in the west-bank facility and 113 in the east-bank fish ladder. Captured fish displayed no facility related injuries and system operational problems for the west-bank fish ladder were identified.

Data related to homing and passage needs of Umatilla River salmonids was investigated in an attempt to maximize return to the Umatilla River. Straying rates of adult summer steelhead and spring chinook salmon were found to be low while coho (oncorhvnchus kisutch) and fall chinook salmon straying rates were high in some groups. High stray rates observed in the past for fall chinook salmon and coho salmon have since improved through efforts in acclimation and release strategies.

Acclimated juvenile fall chinook salmon when released as yearlings in upriver locations displayed relatively low rates of straying while subyearling (age 0+ and 0++) direct releases showed high rates of straying.

Low attraction flows, high water temperatures, and mainstem migrational patterns during the adult fall chinook and coho salmon returns are likely delaying entry of these fish in the Umatilla River (Three Mile Falls Dam). Determination of delay will require information collected at various temperature and flow patterns along with data related to mainstem (Columbia River) movements at various attraction flows.

INTRODUCTION

The Umatilla River, located in northeastern Oregon, originates in the Blue Mountains east of Pendleton, Oregon. Below the headwaters, it flows westerly through dry and irrigated farm lands and enters the Columbia River (RKm 466) below McNary Dam. The Umatilla Basin drainage is approximately 2,290 square miles. Average flow, based on monthly average flows from 1935-1978 at Umatilla are 428 cfs and range from 23 cfs during July to 1,096 cfs during April (CTUIR and ODFW 1990).

Like many other rivers in the Pacific Northwest, the Umatilla River has been highly impacted by man's activities. Although past fish population sizes are unknown, the Umatilla River historically supported large numbers of anadromous salmonids (VanCleve and Ting 1960).

In the early 1900's the lower Umatilla Basin was developed for irrigated agriculture. Irrigation diversion dams drastically reduced instream flows without regard for the needs of anadromous fishes. The entire lower river was often diverted into irrigation canals leaving downstream sections completely dewatered from spring through fall. Many of these same diversion dams provided inadequate or non-existent fish passage facilities which further impacted populations of anadromous fish within the Umatilla River Basin.

Today, work is completed or is being done to improve passage conditions for adult and juvenile anadromous fishes within the Umatilla River. Projects include: instream flow enhancement, juvenile fish screens on irrigation canals, and new or improved fish ladders at irrigation diversion dams. A trap and haul program which transports returning adult salmonids upstream from Three Mile Falls Dam (RKm 6.41, to above Stanfield Dam (RKm 52.1) is also implemented when natural flow conditions do not allow for safe passage in the lower river. The effectiveness of new ladders at irrigation diversion dams is undetermined and the ability of adults to safely migrate past the dams is the uncertainty of this study.

The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) are using radio telemetry to evaluate adult salmonid passage effectiveness in the lower Umatilla River under various flow conditions. The primary objectives of this project are to: (1) evaluate adult passage past five major diversion dams on the lower Umatilla River, (2) evaluate west-bank facility operational. effectiveness at Three Mile Falls Dam, and (3) determine migrational timing and flows necessary for homing to the Umatilla River.

Study Site

Radio telemetry work on the Umatilla River encompassed the entire mainstem system and tributaries upstream of Three Mile Falls Dam (3MD). Primary emphasis was given to five major irrigation diversion dams which have been recently equipped with new fish ladders. These include: Maxwell Diversion Dam (RKm 24.3), Dillon Dam (RKm 40.l), Westland Diversion Dam (RKm 43.8), Feed Canal Dam (RKm 45.4), and Stanfield Dam (RKm 52.3) (Figure 1).

METHODS

Radio Telemetry

Summer steelhead and spring chinook salmon were radio tagged by CTUIR during the adult passage evaluation. Some additional fish tagged at John Day Dam (Columbia River) and Ice Harbor Dam (Snake River) by the University of Idaho Cooperative Fish and Wildlife Research Unit (ICFWRU), were also included in the study. Once recaptured on the Umatilla River at Three Mile Falls Dam, transmitters were removed from all University of Idaho fish to identify the correct channel number, frequency and code. Transmitters were then reinserted and fish were released for evaluation. All information related to tagging and tracking was exchanged with the University of Idaho.

Fish were radio-tagged at various times depending on numbers returning to Three Mile Falls Dam and water flows. An attempt was made to tag fish throughout the adult return period at low, medium, and high water flows. Low water conditions (50-250 cfs) were emphasized because of the prevalence of these conditions in the lower Umatilla River.

Fish utilized for the radio telemetry project were captured in the Three Mile Falls Dam adult trapping facility (east-side) and anesthetized with carbon-dioxide. Summer steelhead were jaw-tagged with tags displaying unique numeric values so that individual fish could be identified at a later date should they regurgitate the radio transmitter. Spring chinook salmon were not jaw-tagged because of concerns associated with high water temperatures and jaw-related injuries during their migrational period (J. Hunt, ICFWRU personal communication, 1992).

Radio transmitters were inserted through the mouth, past the sphincter within the throat, and into the stomach. After tagging, individually tagged fish were slipped into a transport bag and carried from the tagging site to a holding pen in the Three Mile Falls Dam forebay. Tagged fish remained in the pen for one to five hours prior to release to allow retrieval of any regurgitated radio tags.

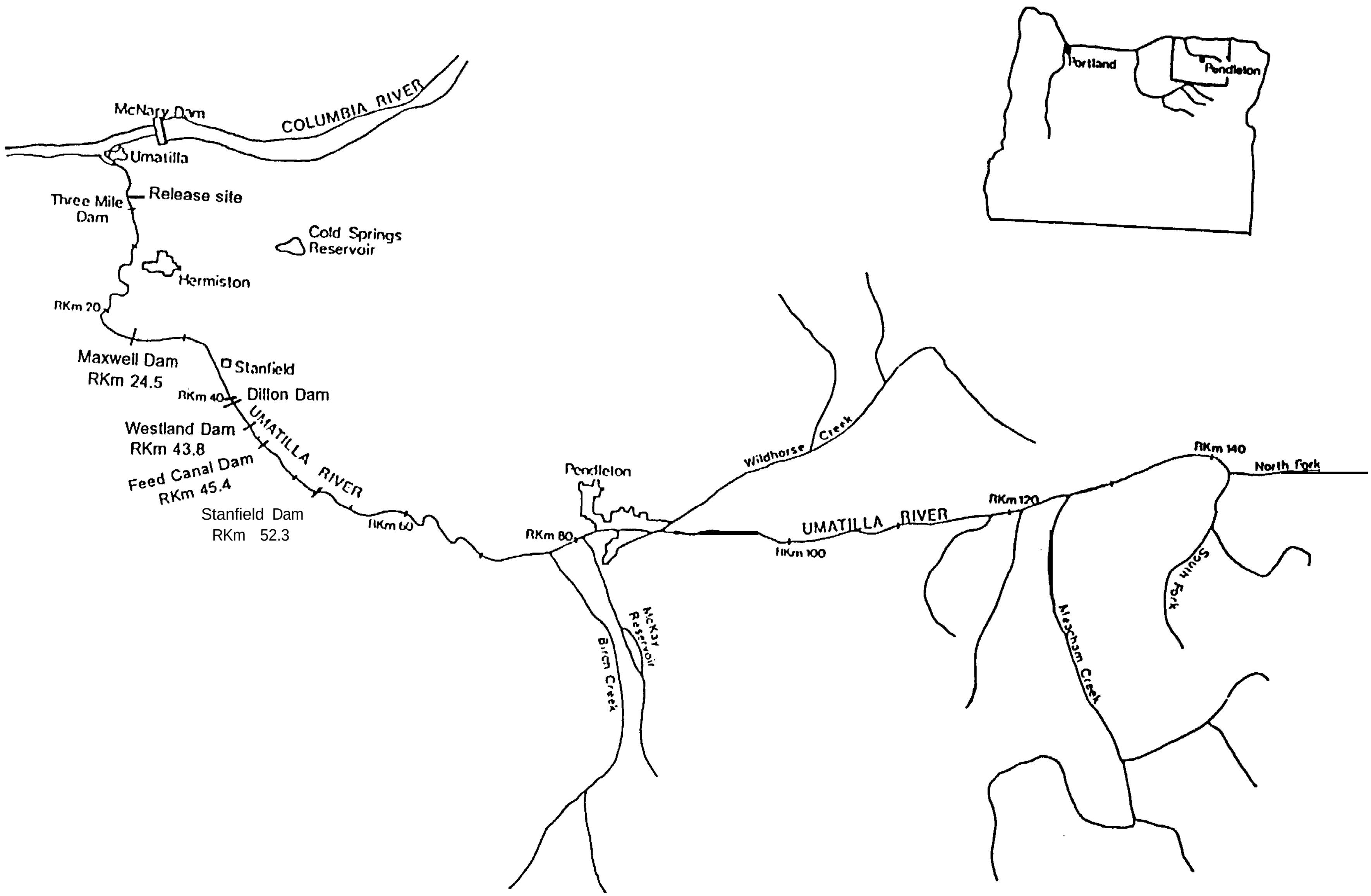


Figure 1. The Umatilla River. Basin, including major tributaries, diversion dams, and release site (Three Mile Falls Dam)

Pulse code radio transmitters obtained for the study were purchased from Lotek Engineering in Newmarket, Ontario. Tags were high frequency 150 MHz, with a frequency spacing between tags of approximately 30 KHz. Transmitters used for summer steelhead were 4.5 centimeters long,, 1.1 centimeters in diameter and had a minimum operating life of three months. Spring chinook salmon transmitters were 4.5 centimeters long, 1.6 centimeters in diameter, and had a minimum operating life of eight months.

Depending on location, tagged fish were radio tracked on a weekly and sometimes daily basis using a Lotek SRX 400 radio telemetry receiver. Unlike CTUIR "pulse tags" which send out between 50 and 95 beats per minute, University of Idaho tags are "coded" and transmit a signal 12 times per minute (once every five seconds). Because of this, the receiver was programmed to scan each frequency for six seconds so that an overlap of CTUIR and University of Idaho tags would be ensured.

Four element antennas (made by Cushcraft and Lindsay Specialty Products) utilized for radio tracking were either hand-held or installed in a pickup truck for mobile tracking. Radio tracking (with the receiver) involved driving and/or walking the portion of the river in which the tagged fish was last located and expanding beyond that area if the fish was not present. Once located, the receiver was used to secure a more precise location of the tagged fish. This was accomplished by observing power readings on the receiver in relationship to antenna direction. Extra effort to determine exact location (within 10 meters) was given when tagged fish were at or near diversion dam locations.

Migrational movements of radio-tagged fish in relationship to water temperatures and river flows were included in the study. Water temperatures (generated at Three Mile Falls Dam) and river flows were provided by Zimmerman and Duke (1993).

Three Mile Falls Dam West-Bank Operation

The west-bank facility at Three Mile Falls Dam was operated from April 12 through April 16, 1993 to evaluate adult migration and gain system operational experience. The facility was operated within criteria developed by the National Marine Fisheries Service (NMFS). Before operation began, one day was spent with the United States Bureau of Reclamation (USBR) learning operational procedures and identifying any mechanical system problems. Video monitor equipment was installed within the viewing window so that video enumeration could be included in the study. Two boards were attached to the V-notch entrance bars on the adult trap to reduce escape of trapped fish. Because the existing fish removal system was not considered to be functional, fish were removed on a daily basis by "dewatering" the facility and dip-netting the fish out of the adult trap and fish ladder.

Migrational Timing and Homing Needs

Available data on returning adult coho, fall and spring chinook salmon, and summer steelhead was analyzed in an attempt to determine the time and amount of flow necessary to maximize return into the Umatilla River. All information related to known Umatilla River origin fish was considered in the search. This included juvenile release data, coded wire-tag recoveries from Pacific States Marine Fisheries Commission (PSMFC), and radio telemetry data from the University of Idaho Cooperative Fish and Wildlife Research Unit (ICFWRU) . Water flow data was obtained from the United States Bureau of Reclamation (USBR), and temperature data from a thermograph placed at Three Mile Falls Dam. Determination of homing and straying rates was accomplished by using coded wire-tag estimated expansion numbers from Rowan (1992).

Acclimated and direct release evaluation experiments were conducted on the Umatilla River during the years 1988-91. Much of this data was not used because of inconsistencies in the experimental approach. Any comparison of experimental groups at different sizes, different release locations, different release dates, or with severe disease problems, were excluded from the evaluation.

RESULTS

Radio Telemetry

Summer Steelhead

A total of 13 summer steelhead were radio-tagged between December 15, 1992 and May 12, 1993 and eight (61%) of these were observed successfully negotiating the lower 32 miles of the Umatilla River. Three steelhead regurgitated-the radio transmitter and one tag is believed to have failed shortly after tagging. The remaining fish was last located at RKm 12.9 (Figure 2).

Migrational behavior of summer steelhead was highly variable. Some remained in one location for as long as five weeks while others displayed nearly constant upstream migration (figures 3 and 4). Time required for summer steelhead to complete migration from release site to the uppermost diversion dam (Three Mile Falls Dam RKm 6.4 to Stanfield Dam RKm 52.3) ranged from a high of 84 days to a low of 3 days with an average of 30 days needed to complete the distance.

Migratory distance per day appears to be closely related to water temperatures, river flows, and Umatilla River date of entry. Summer steelhead entering the Umatilla River during the winter months, displayed little or no upstreammovements during cold-water spells (< 5.6C or 42F), (Figures 5 and 6). River flows in the Umatilla River did not appear to have as much effect on movements except at very high flows. This was especially evident at or near diversion dam areas (Figure 7). Date of entry into the Umatilla River also influenced migrational habits of steelhead. Fish radio-tagged later in the migrational period such as those entering in April and May (Figure 4), moved upstream faster and more constant than those entering early in the migrational period (Figure 3).

Spring Chinook Salmon

Between April 22, 1993 and May 19, 1993 a total of ten spring chinook salmon were radio-tagged at Three Mile Falls Dam. Of these, five were radio-tagged at John Day Dam by the University of Idaho and recaptured at Three Mile Falls Dam after entering the Umatilla River. Migrational patterns for spring chinook salmon were as follows: Seven (70%) spring chinook salmon were observed successfully migrating past the major diversion dams, one radio transmitter was regurgitated, and one chinook salmon was trapped within Westland Canal. One other chinook salmon, tagged on May 3, 1993 remained at the release site for several days but then could not be found. The fish was then recaptured at Three Mile Falls Dam on June 4, 1993 and hauled upstream to RKm 140 (Figure 8).

Time needed to complete the distance from release site to the uppermost diversion dam was less for spring chinook salmon than observed for summer steelhead. Average time required was 11 days with a high of 21 days and a, low of 4 days.

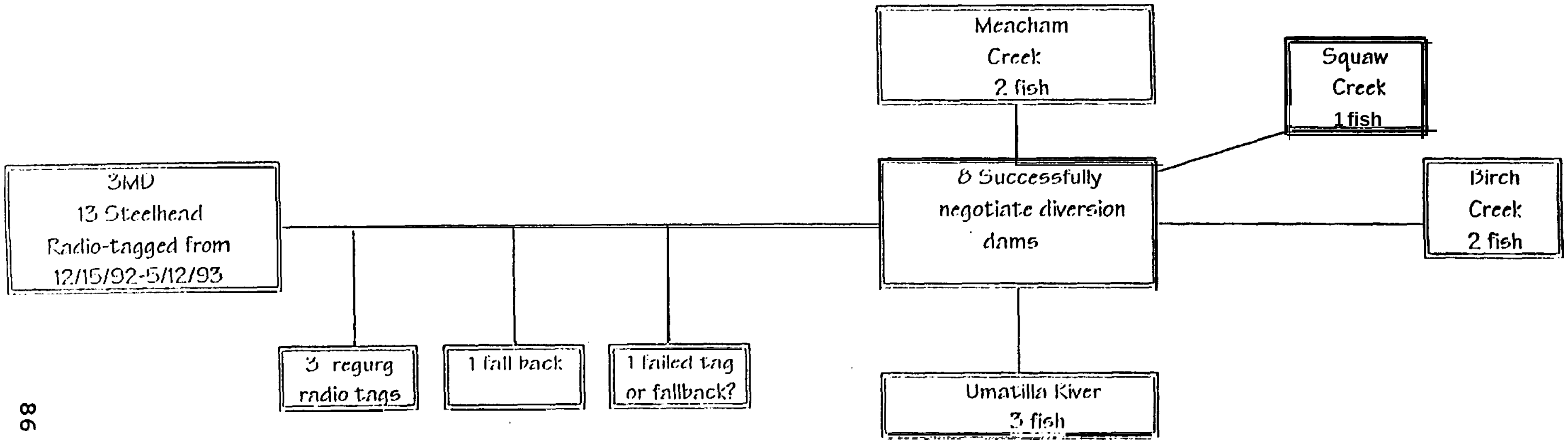
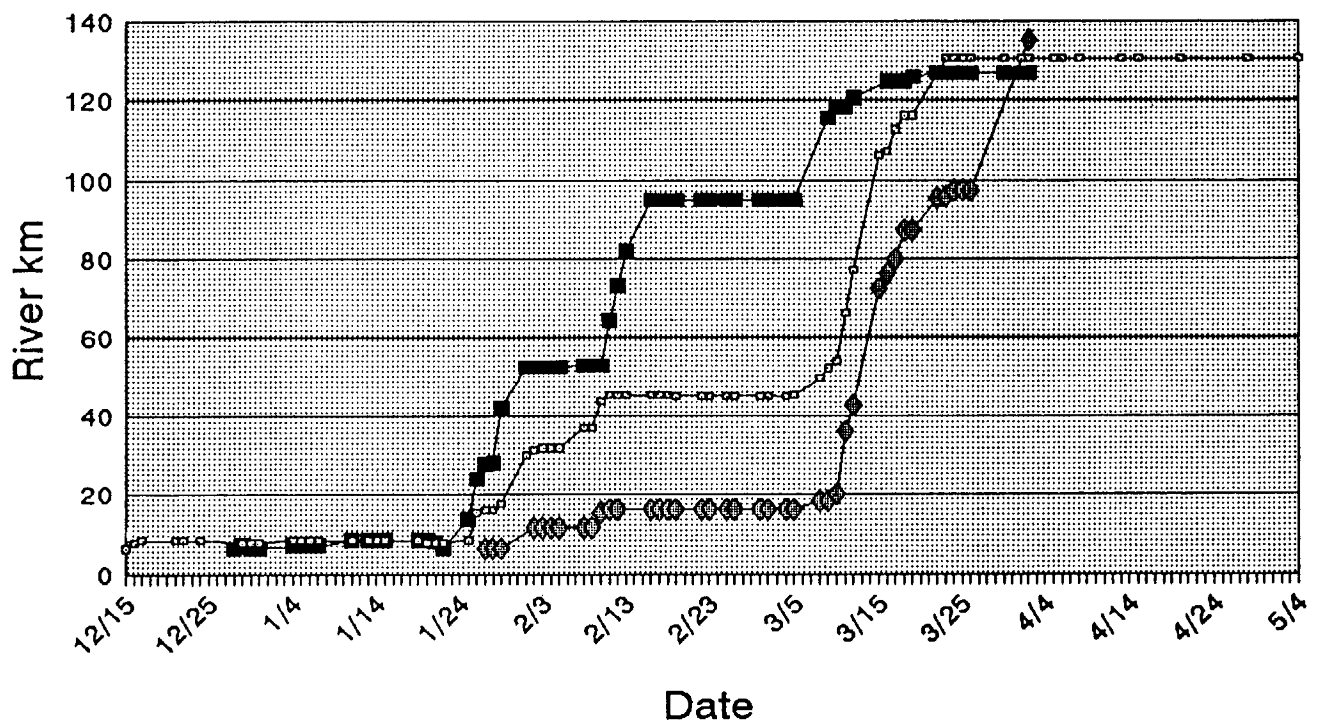


Figure 2. **Flow chart for radio tagged summcr steelhend showing migrational movements in the Umatilla River Basin 1992/93 Note: Some locations on chart: nre "last known locations" nnd may not be indicative of final dcstlnntlon.**

Figure 3.

Summer Steelhead Migrational Behavior

Umatilla River (1992/93)



Tags 1, 4, 13 (released at RKm 6.4)

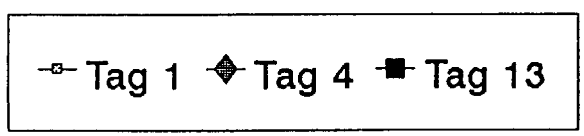
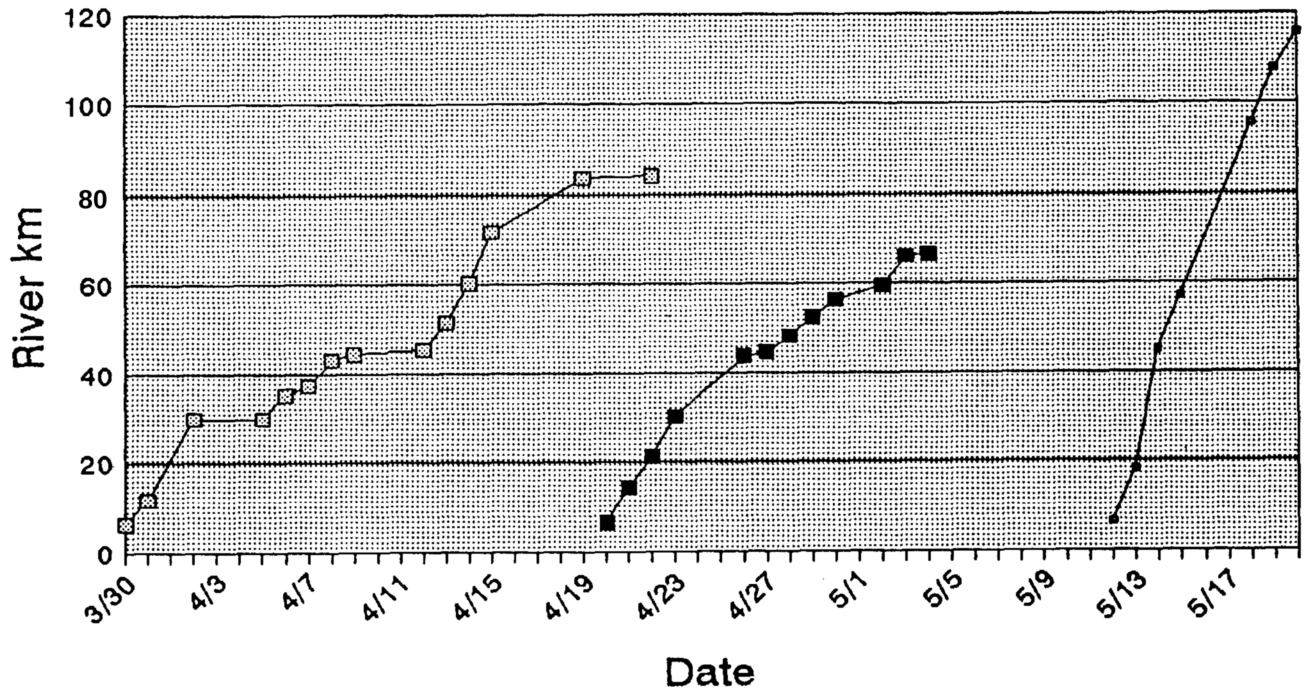


Figure 4.

Summer Steelhead Migrational Behavior

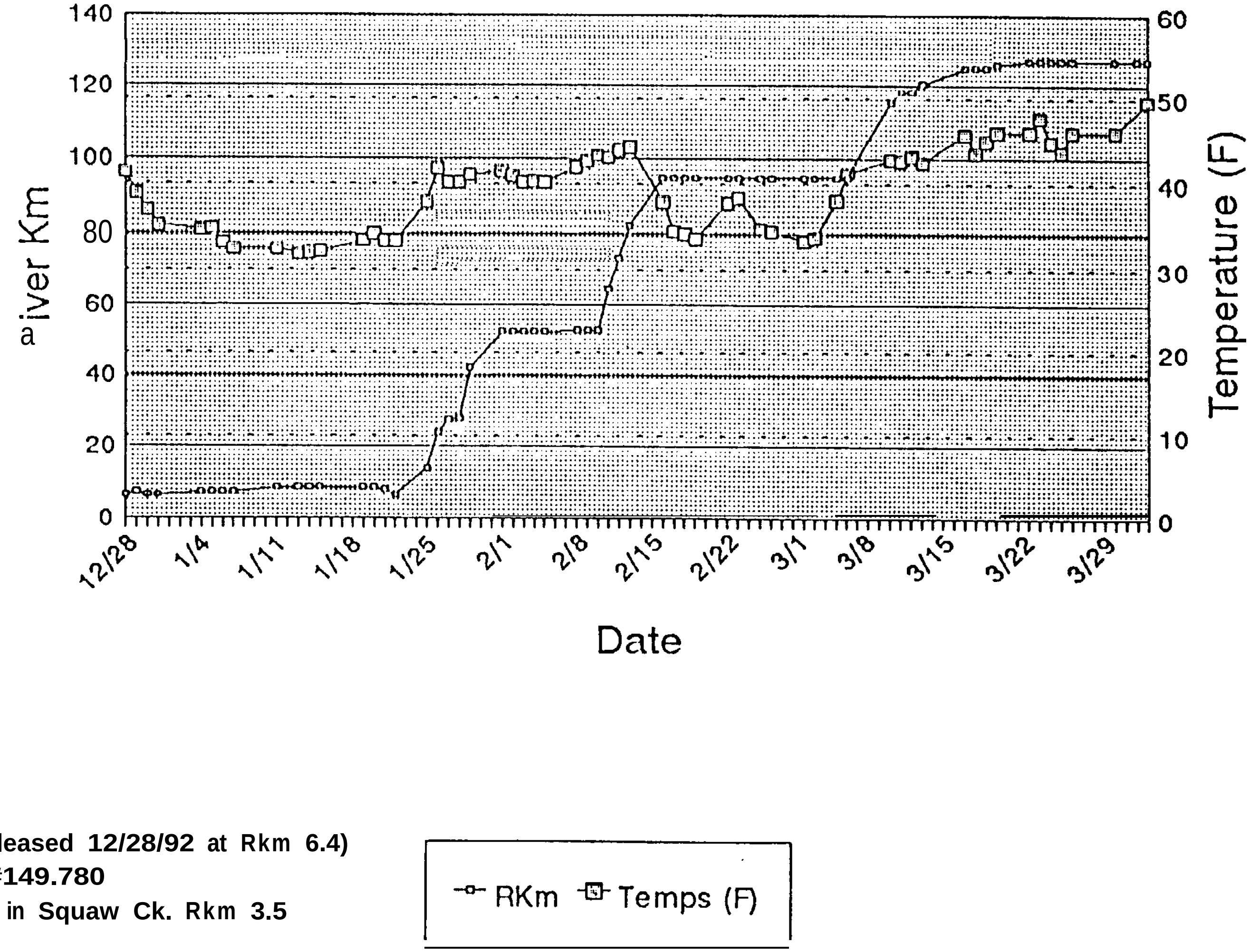
Umatilla River (1993)



Tags 9, 12,II
Released at Three Mile Falls Dam (RK

Figure 5.

Summer Steelhead Migrational Behavior vs Temperature
Umatilla River (1992/93)

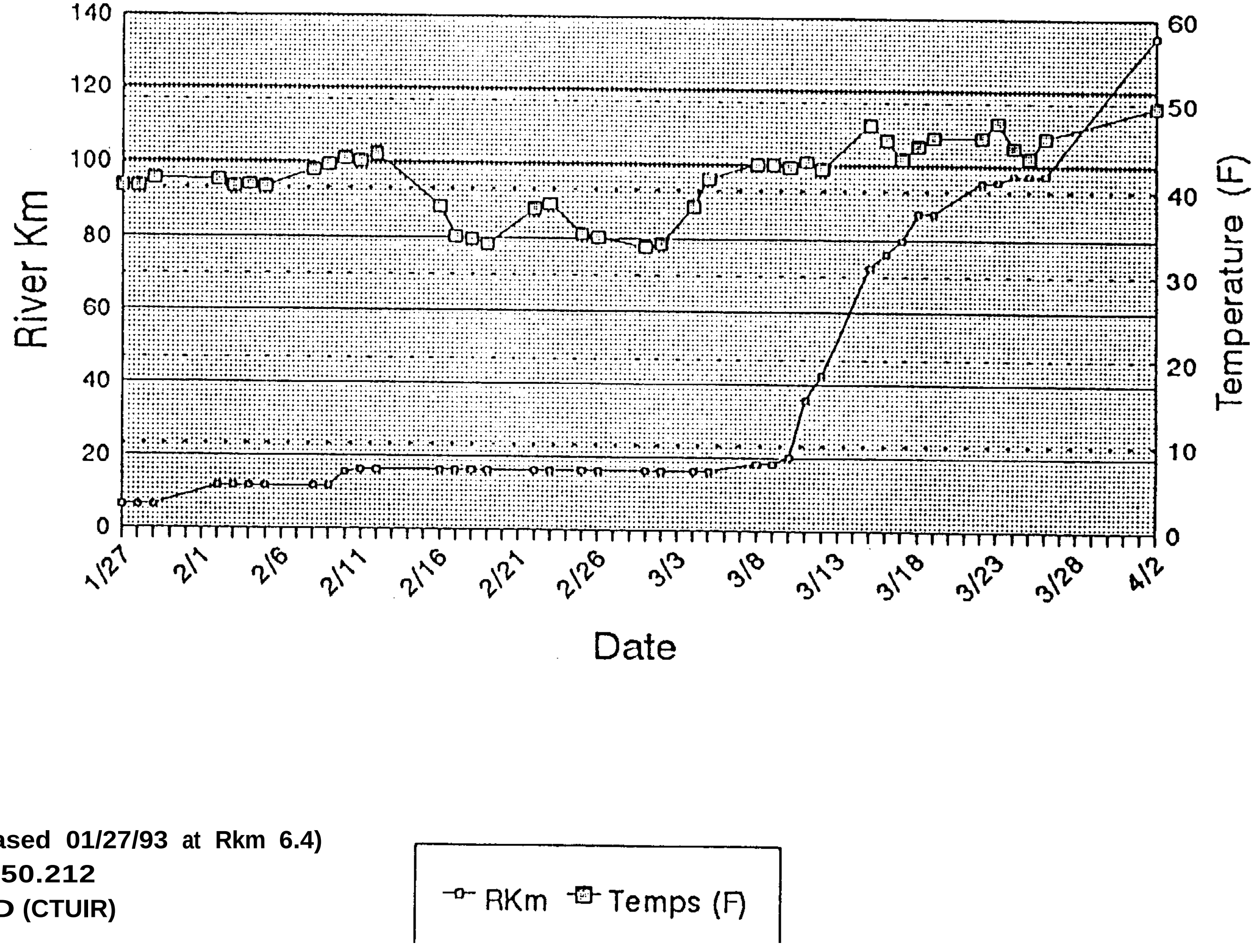


Tag #13 (released 12/28/92 at Rkm 6.4)
Frequency #149.780
Last located in Squaw Ck. Rkm 3.5

Figure 6.

Summer Steelhead Migrational Behavior vs Temperature

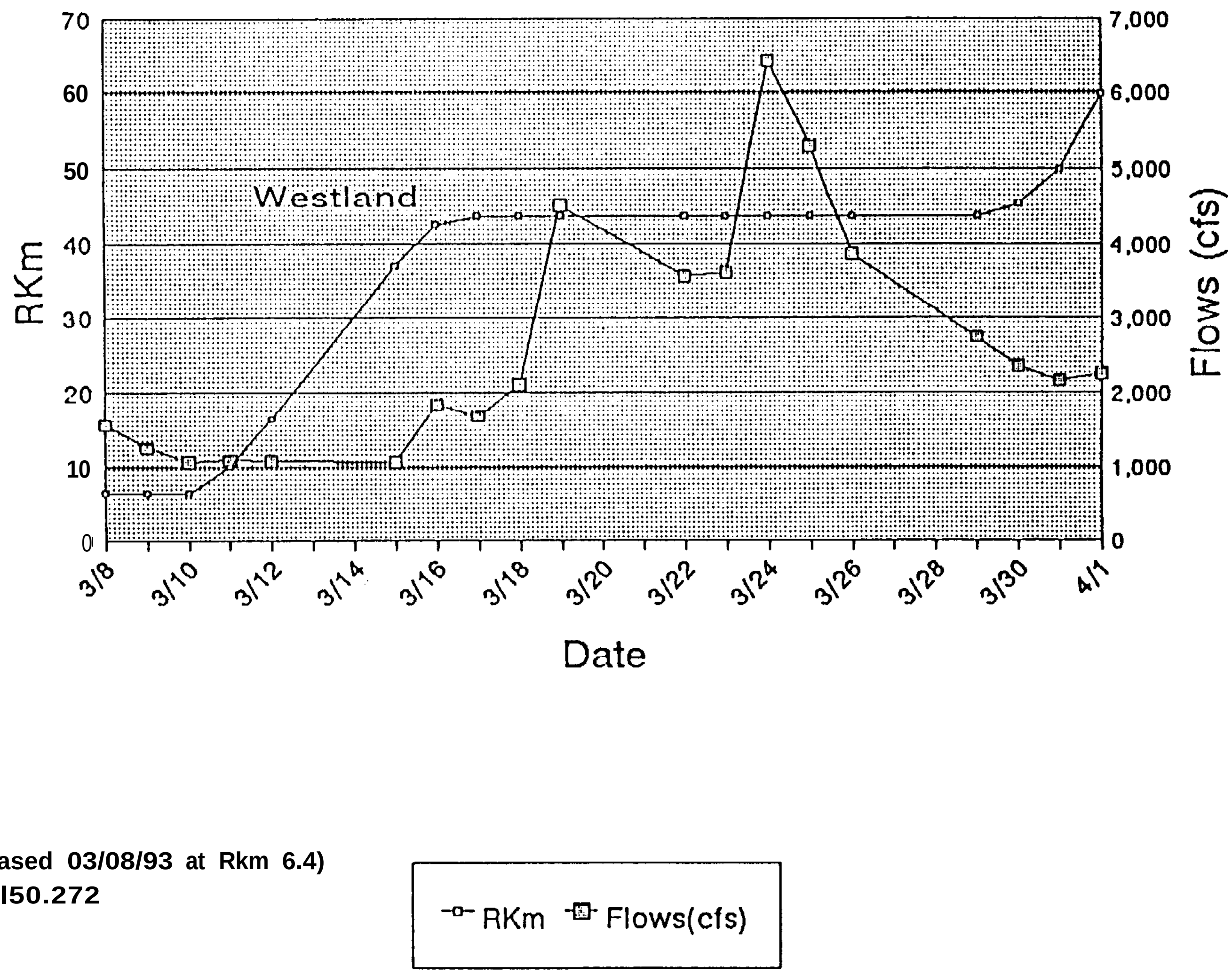
Umatilla River (1993)



Tag #4 (released 01/27/93 at Rkm 6.4)
Frequency #l50.212
Temps @3MD (CTUIR)

Figure 7.

Summer Steelhead Migrational Behavior vs Flow
Umatilla River (1993)



Tag #6 (released 03/08/93 at Rkm 6.4)
Frequency #l50.272

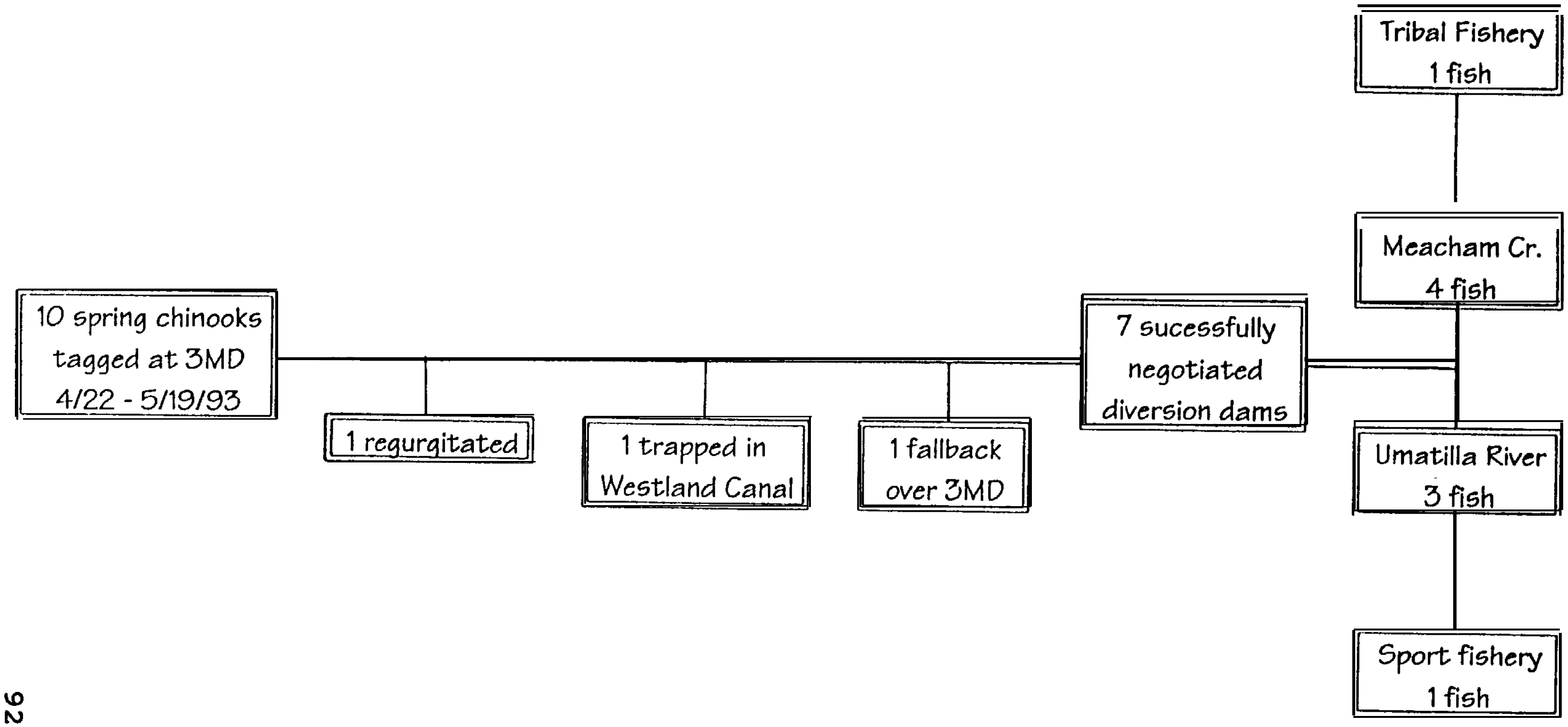


Figure 8. Flow chart for radio tagged spring chinook showing migrational movements in the Umatilla River Basin 1993.
Note: Some locations on chat-t are "last known locations" and may not be indicative of final destination.

When compared to migratory rate between diversion dams, travel time for spring chinook salmon at diversion dams appears to be increased. This was especially apparent at Feed Canal Dam as river flows receded. Spring chinook salmon encountering Feed Canal Dam during high water flows (greater than 650 cfs) demonstrated little or no hesitation at the diversion dam (Figure 9) while fish approaching the structure at flows less than-450 cfs, displayed difficulty (delay) in negotiating the dam (Figure 10).

Fall Chinook and Coho Salmon

Because of low river flow conditions and late entry to Three Mile Falls Dam, coho salmon and fall chinook salmon were not radio tagged during the 1992-93 passage study.

Three Mile Falls Dam West-Bank Operation

A total of 130 summer steelhead were captured at Three Mile Falls Dam during the four-day test period of which 17 (13%) were captured in the west-bank facility and 113 on the east bank. All fish appeared in good health and displayed no facility-related injuries. Given the current condition of the west-bank facility, it should be operated only in the bypass mode. The facility has severe problems associated with trapping, hauling and/or sampling of adult salmonids. The following operational problems were identified for the west-bank facility:

1. Water in backlight chamber
2. No automatic stop on horizontal crowder
3. No sort or enumeration capabilities for captured adults.
4. V-notch entrance gate bars on adult trap need to be spaced closer so that trapped fish do not escape.
5. Metal fish panel (FP-1) missing on side of adult trap and fish likely to jump into opening if not replaced.
6. Entrance gates (G-l, G-2) difficult and time consuming to operate manually. Should be power driven so that head differential needs can be met more quickly and easily as fluctuations in river flows occur.
7. The existing fish-lock hoist and transfer mechanism does not allow fish to be effectively and safely transferred from the adult trap to the transport vehicle.

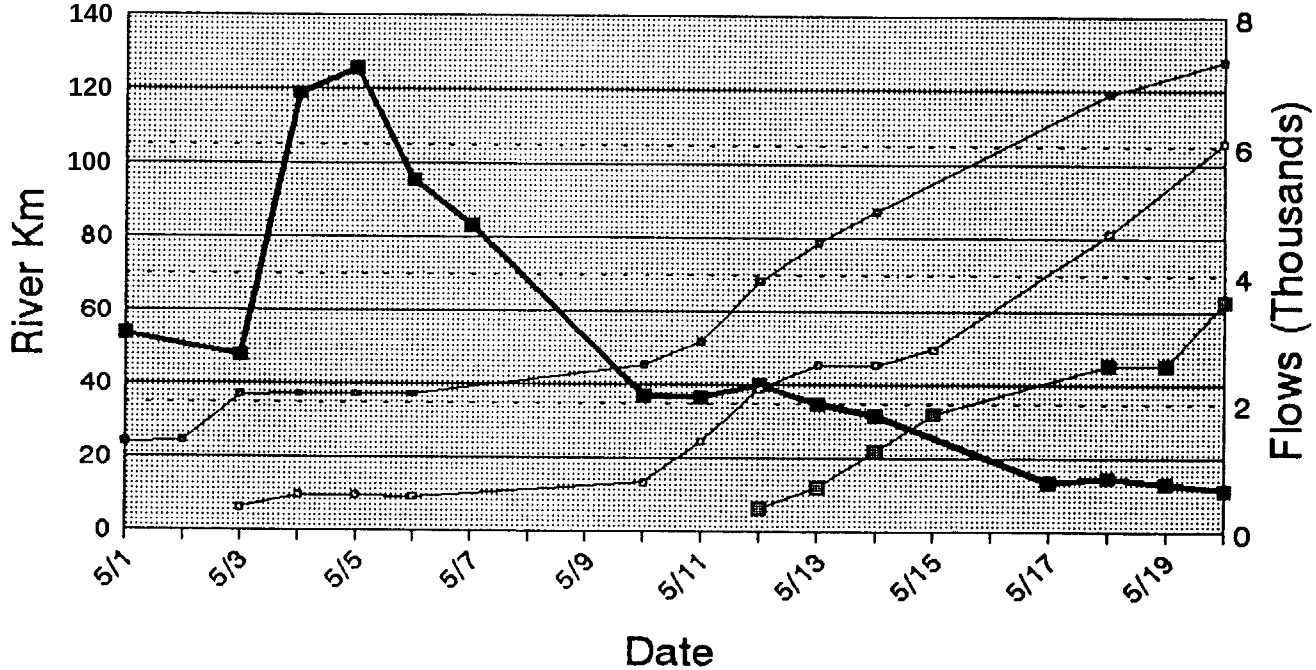
Migrational Timing and Homing Needs

Umatilla River acclimated versus direct (evaluation experiments) releases of age 0++ juvenile fall chinook salmon had homing rates of 50% for acclimated fish and 38.5% for direct releases (Table 1).

Figure 9.

Spring Chinook Migrational Behavior

Umatilla River (1993)



Tags 2, 4,16
Feed Canal Dam RKm 45.4
Released at RKm 6.4

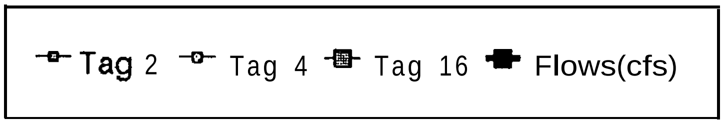
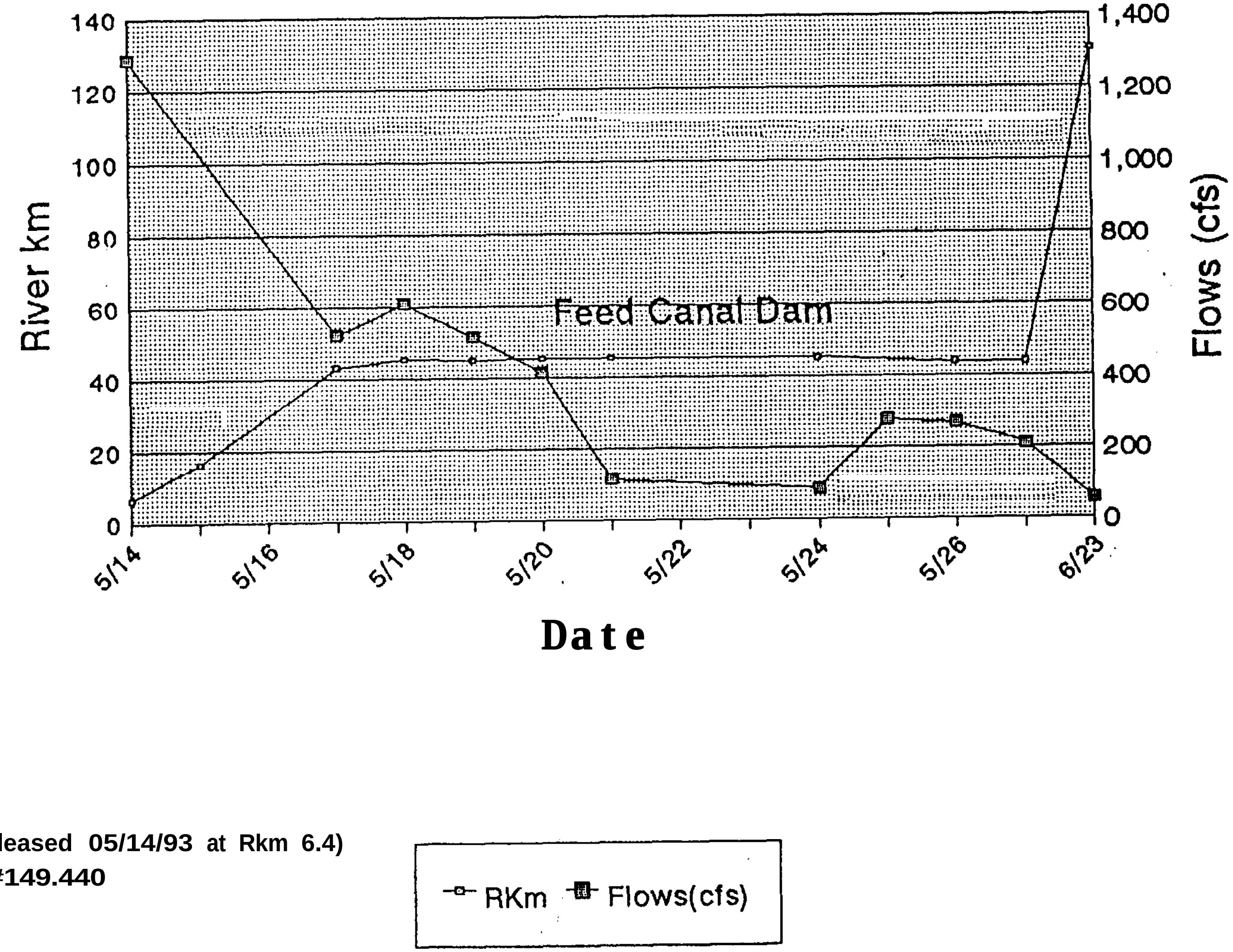


Figure IO.

Spring Chinook: Migrational Behavior

Umatilla River (1993)



Tag #19 (released 05/14/93 at Rkm 6.4)
Frequency #149.440

Table 1. Umatilla river homing & straying information for acclimated versus direct (evaluation experiment) releases of age 0++ juvenile fall chinook salmon.								
Acclimated vs direct (evaluation experiment):								
Br.Yr	Tag Code	Rel. Loc.	Total Released	Rel. Age	No. Above McNary	No. to Umatilla	% home	% stray
88	074758,60,63	Nr. Minthorn	78132	o++	8	5	38.5	61.5
88	0747536457	Minthorn	78825	o++	7	7	50.0	50

0+ = spring or summer release

Homing rates versus age at release for juvenile fall chinook salmon showed age 1+ fish homing to the Umatilla River in the greatest numbers. Acclimated (Bonifer and Minthorn) age 1+ fish had a weighted average homing rates of 75.3% with. a range of 33.5% to 88.4%. Homing rates for acclimated age 0++ fish had weighted average rates of 13.7% and a range of rates from 3.4% to 50% (Table 2).

Table 2. Umatilla River homing and straying rate for acclimated age OH- and 1+ Juvenile fall chinook salmon.

Age 1+ releases:

Br.Yr.	Tag Code	Rel. Loc.	Total Released	Rel. Age	No. Above McNary	Nato Umatilla R.	% home	% stray
84	073327	Mlnthom	91036	1+	113	57	33.5	66.5
85	073823/27	Minthorn	109143	1+	29	220	86.4	11.6
85	073828/32	Bonifer	102363	1+	69	129	65.2	34.8
86	074038139	Minthorn	160791	1+	46	291	86.4	13.6
86	074036/37	Bonifer	99550	1+	43	216	83.4	16.6

Age 0++ releases:

Br. Yr.	Tag Code	Rel. Loc.	Total Released	Rel Age	No. Above McNary	No. to Umatilla R.	% home	% stray
84	073162	Bonifer	51000	0++	17	3	15.0	85.0
89	075325/27	Minthorn	71863	0++	1	1	50.0	50.0
88	074753,54,57	Minthorn	78825	0++	7	7	50.0	50.0
87	074539/41	Minthorn	14408	0++	57	2	3.4	96.6

0++ = Fall release

Subyearling (age 0+ and Ott) direct releases of fall chinook salmon in the Umatilla River had weighted average homing rates of 53% with a range of zero to 66.7% (Table 3).

Table 3. **Umatilla River homing & straying rates for direct release age 0+ and 0++ juvenile fall chinook salmon.**

Br. Yr.	Tag Code	Rel. Loc.	Total Released	Rel. Age	No. Above McNary	No. to Umatilla R.	% home	% stray
89	075403-05	RM 70-79	2425681	o+	229	245	61.7	48.3
89	075322-24	Nr. Minthorn	76646	0++	3	0	0.0	100.0
87	07453836	Nr. Minthorn	76681	Ott	24	48	66.7	33.3
88	074758,60,63	Nr. Minthorn	78132	o++	8	5	38.5	61.5

0+ = spring release
0++ = fall release

Harvest data analyzed by Kissner (1993) found that Umatilla River adult fall chinook salmon are first harvested in the John Day Pool during the period August 24-30 and peaked in mid-September. In addition, coded wire tag data collected on the Snake River in 1992, showed that peak migration for straying Umatilla River origin fall chinook salmon over Ice Harbor Dam was from September 10 through September 16 (Figure 11). This clearly demonstrates that Umatilla River origin fall chinook salmon are within the mainstem Columbia River above or below the mouth of the Umatilla River in early September. However, entry dates of fall chinook salmon in the Umatilla River (as determined by count at Three Mile Falls Dam) during the last four return years were not significant until mid to late October.

In both 1990 and 1991, entry of fall chinook salmon began to increase as flows increased and water temperatures were declining (Figures 12-15). In 1989 however, the Umatilla River experienced flows below Three Mile Falls Dam of greater than 150 cfs during the first two weeks of October (Figure 16), yet few fish arrived at Three Mile Falls Dam until October 19-26. Temperatures at this time (55-65 degrees during first two weeks of October-1989)were declining but were still above the levels observed during the major migratory entry periods in 1990 and 1991 (Figure 17). This would suggest that temperature may be delaying entry.

Table 4 shows Umatilla River fall chinook salmon returns and strays versus average attraction flows during the first two weeks of October for the 1989 and 1990 return years. During this period, the Umatilla River experienced average attraction flows of 160 cfs during 1989 and 59 cfs during 1990. Despite the increased attraction flows during 1989, stray rates were still greater than those experienced during the 1990 return.

Figure 11.

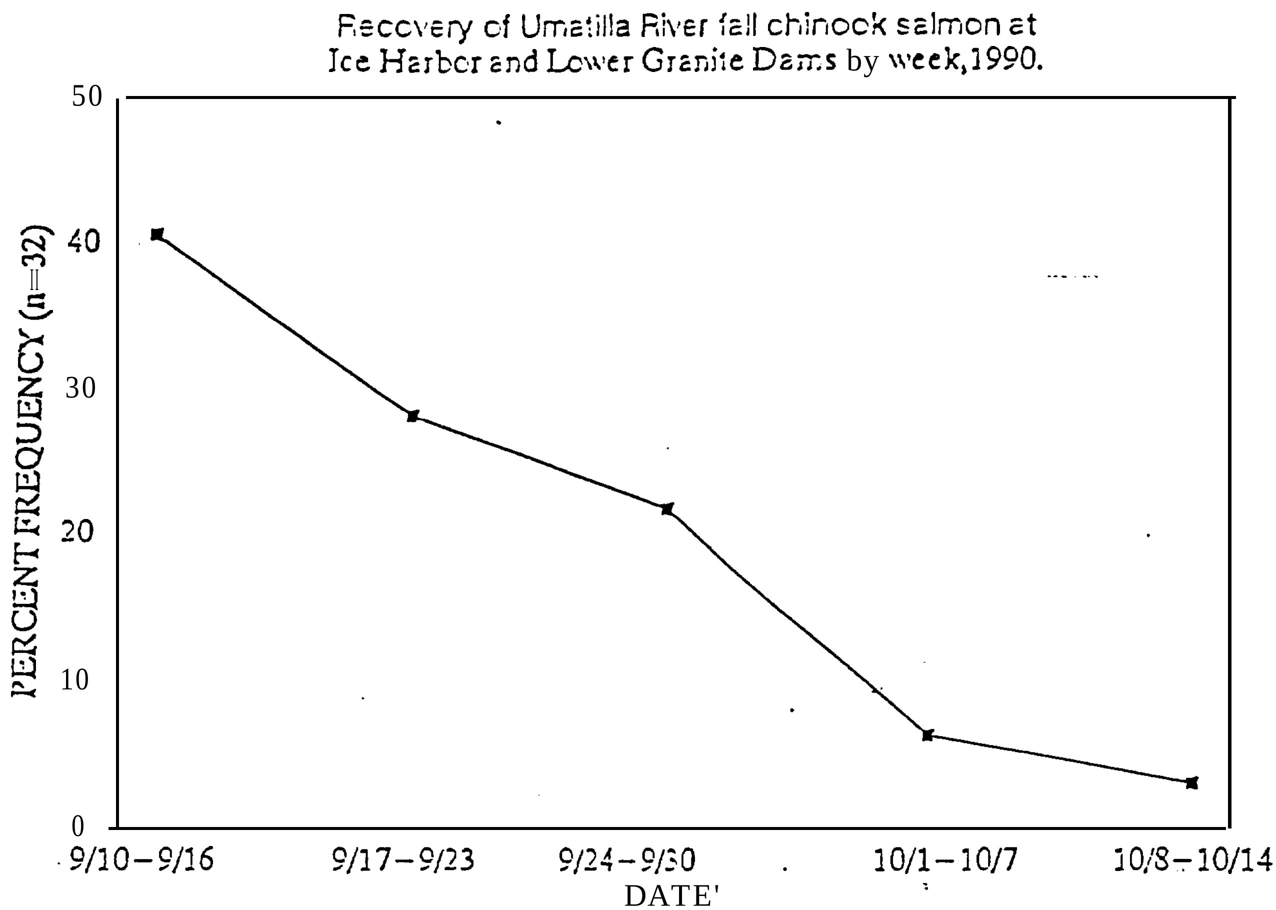

Recovery of Umatilla River fall chinook salmon at
Ice Harbor and Lower Granite Dams by week, 1990.
PERCENT FREQUENCY (n=32)
50
40
30
20
10
0
9/10-9/16
9/17-9/23
9/24-9/30
10/1-10/7
10/8-10/14
DATE'

Figure 12.

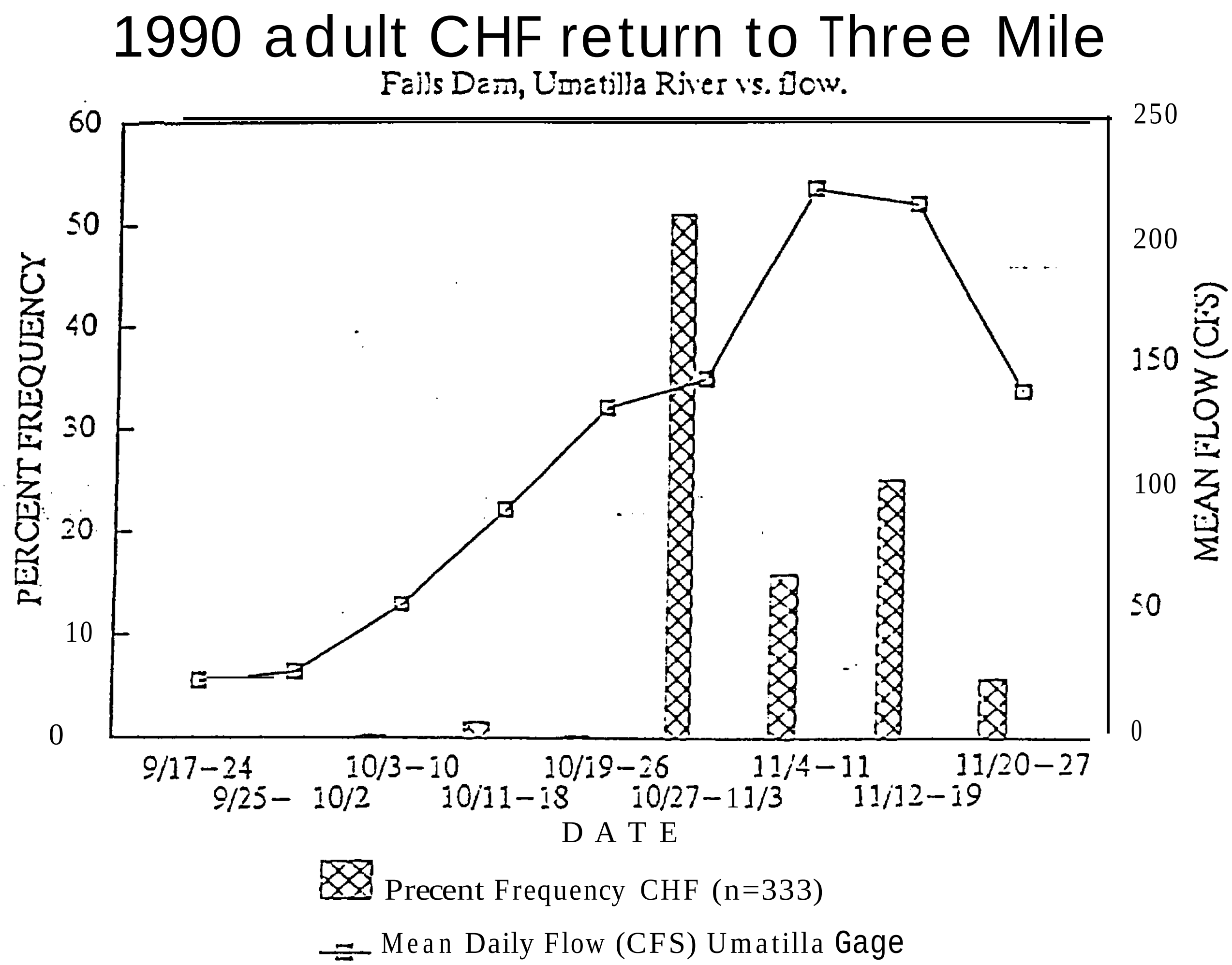

1990 adult CHF return to Three Mile
Falls Dam, Umatilla River vs. flow.
PERCENT FREQUENCY
MEAN FLOW (CFS)
60
50
40
30
20
10
0
250
200
150
100
50
0
9/17-24
9/25- 10/2
10/3-10
10/11-18
10/19-26
10/27-11/3
11/4-11
11/12-19
11/20-27
DATE
Precent Frequency CHF (n=333)
Mean Daily Flow (CFS) Umatilla Gage

Figure 13.

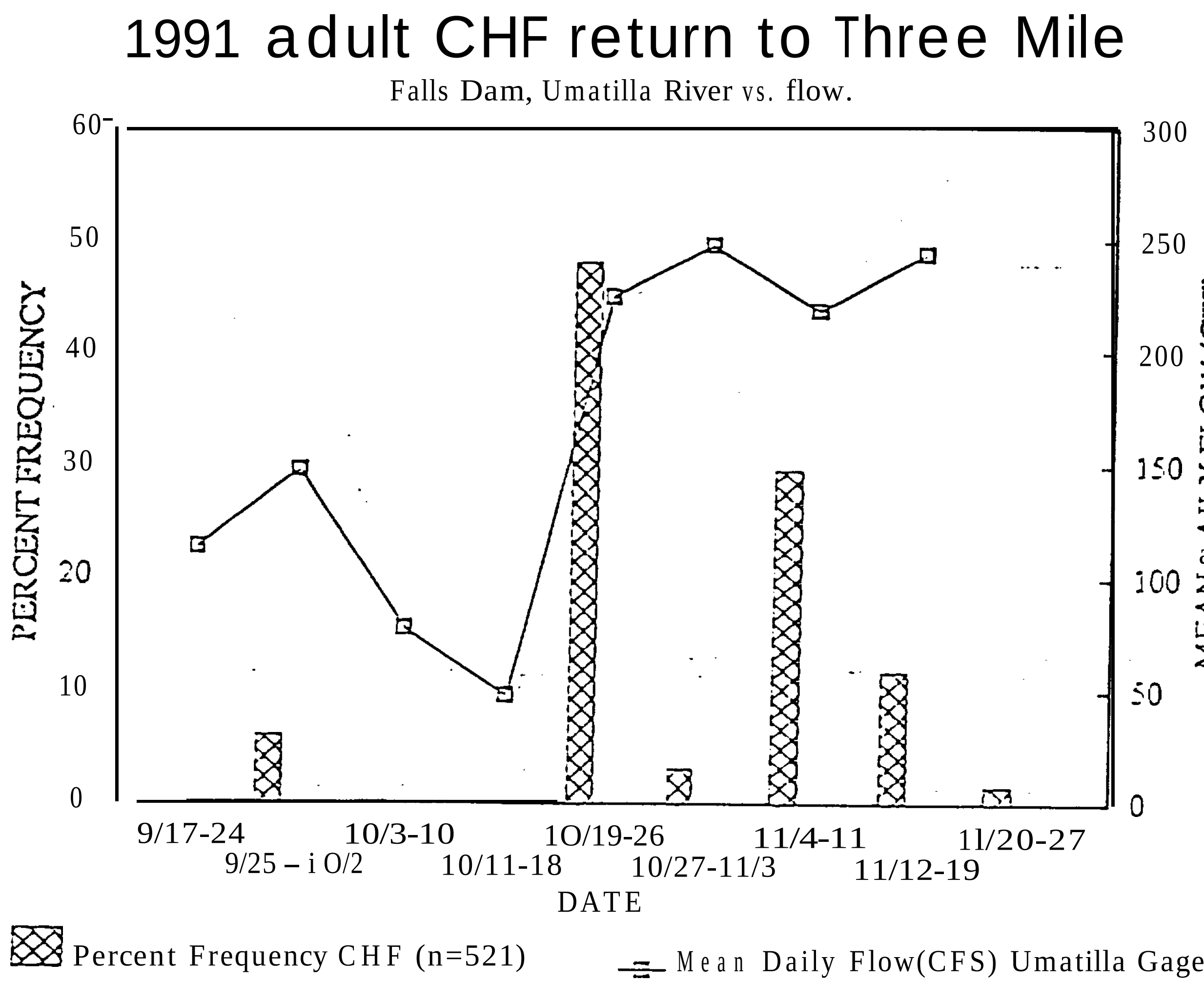
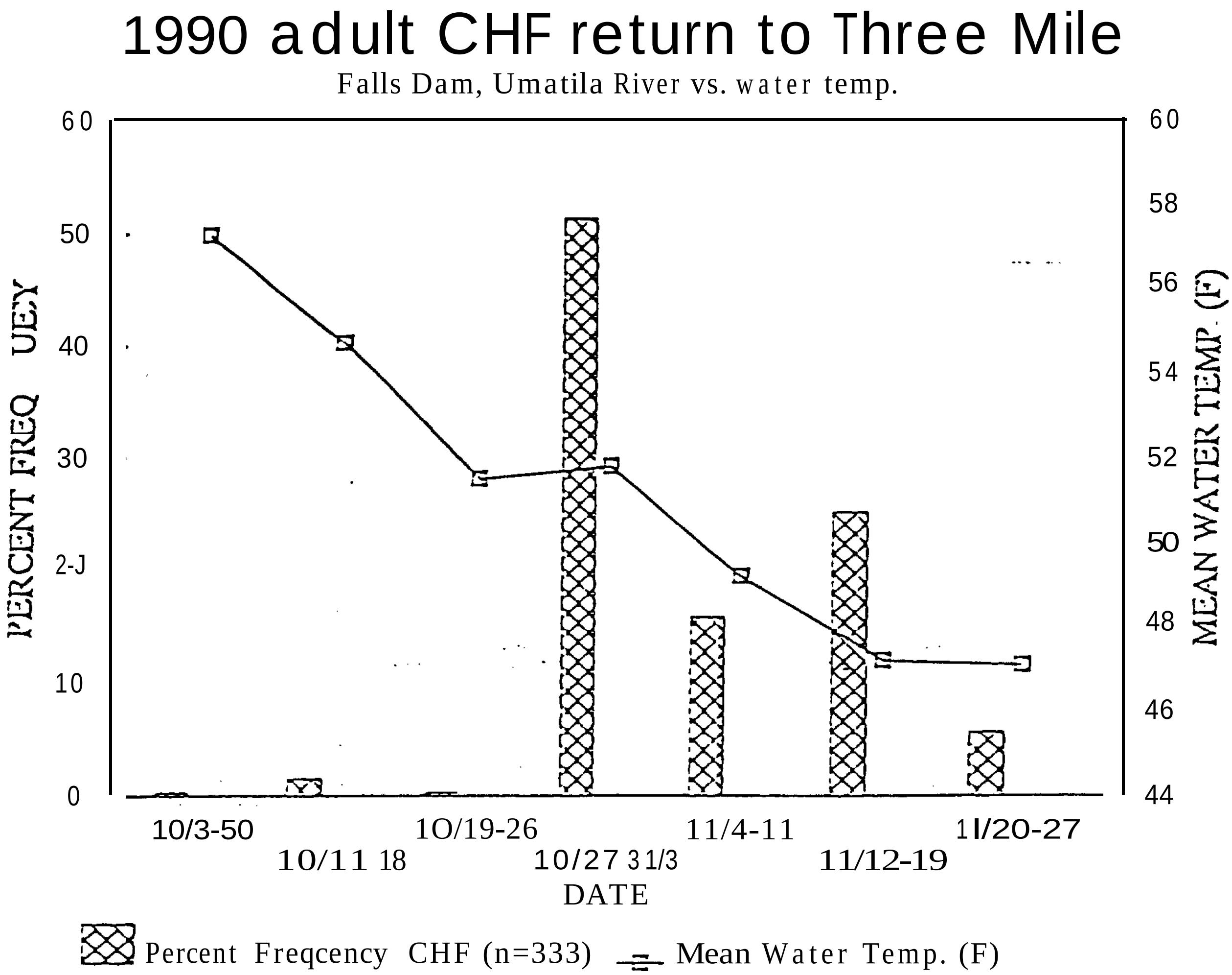
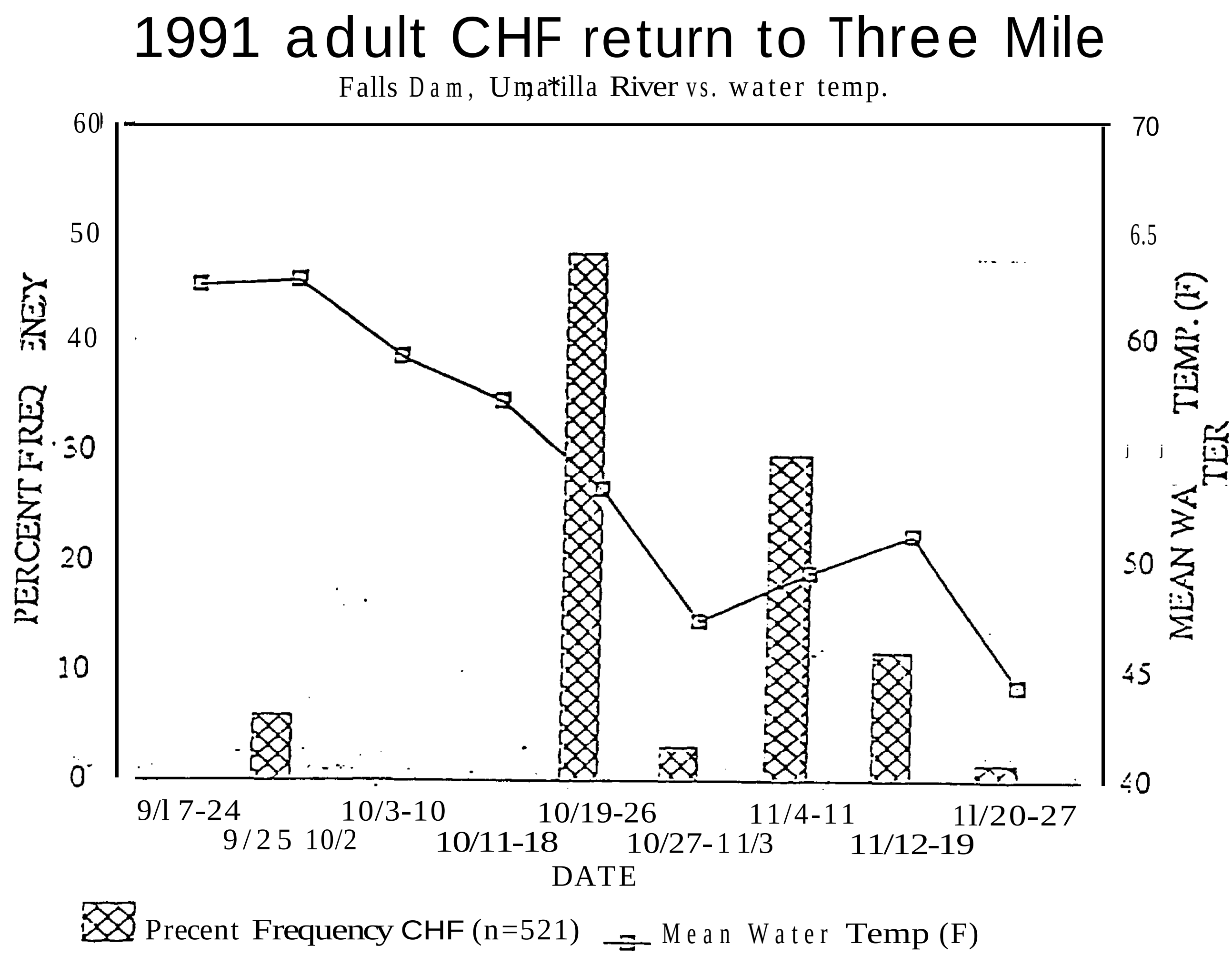

1991 adult CHF return to Three Mile
Falls Dam, Umatilla River vs. flow.
60
50
40
30
20
10
0
PERCENT FREQUENCY
300
250
200
150
100
50
0
MEAN DAILY FLOW (CFS)
9/17-24
9/25-10/2
10/3-10
10/11-18
10/19-26
10/27-11/3
11/4-11
11/12-19
11/20-27
DATE
Percent Frequency CHF (n=521)
Mean Daily Flow(CFS) Umatilla Gage

Figure 14.



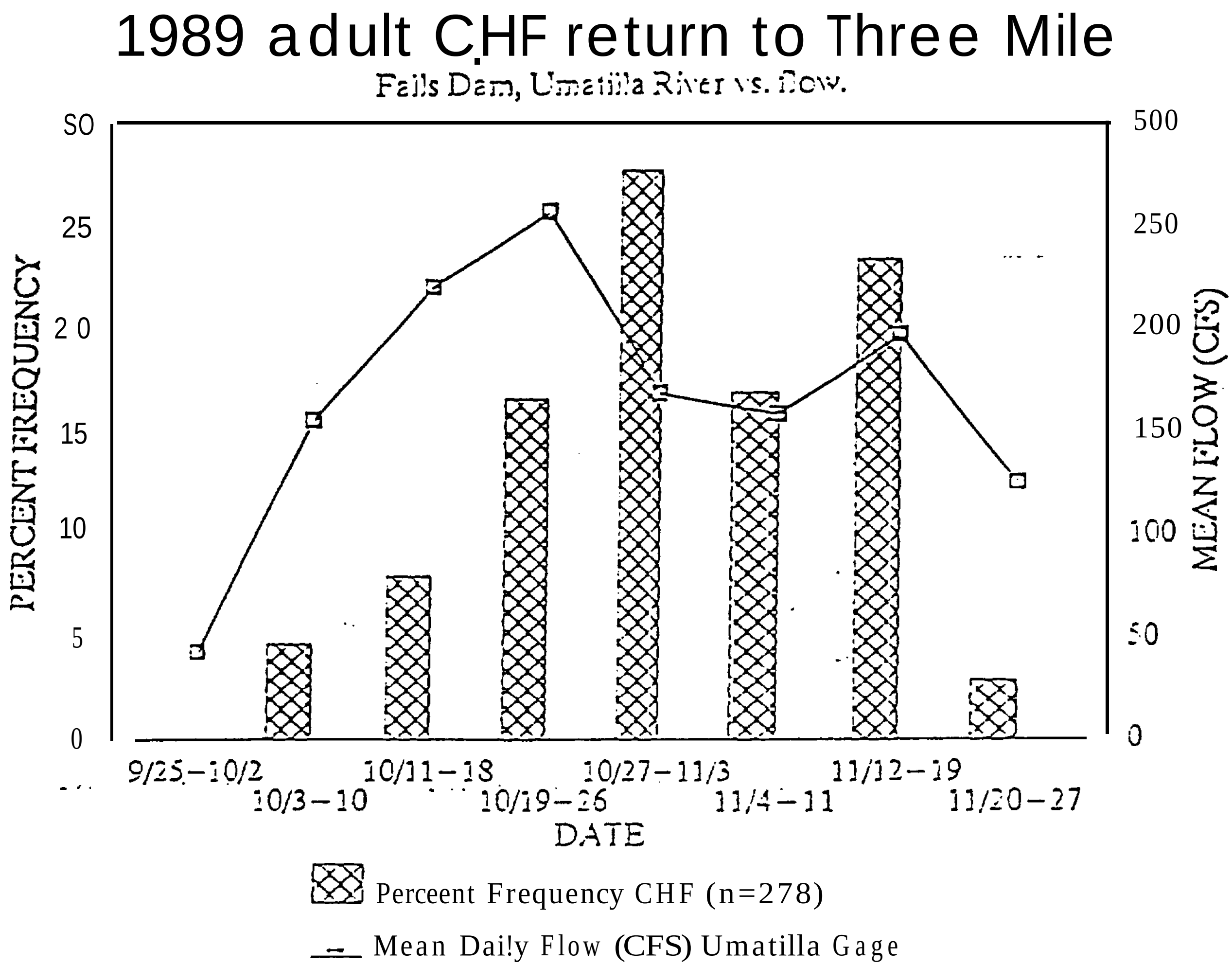
1990 adult CHF return to Three Mile
Falls Dam, Umatila River vs. water temp.
PERCENT FREQ UEY
MEAN WATER TEMP. (F)
60
50
40
30
2-J
10
0
60
58
56
54
52
50
48
46
44
10/3-50
10/11 18
1O/19-26
10/27 31/3
11/4-11
11/12-19
1I/20-27
DATE
Percent Freqcency CHF (n=333)
Mean Water Temp. (F)

Figure 15.



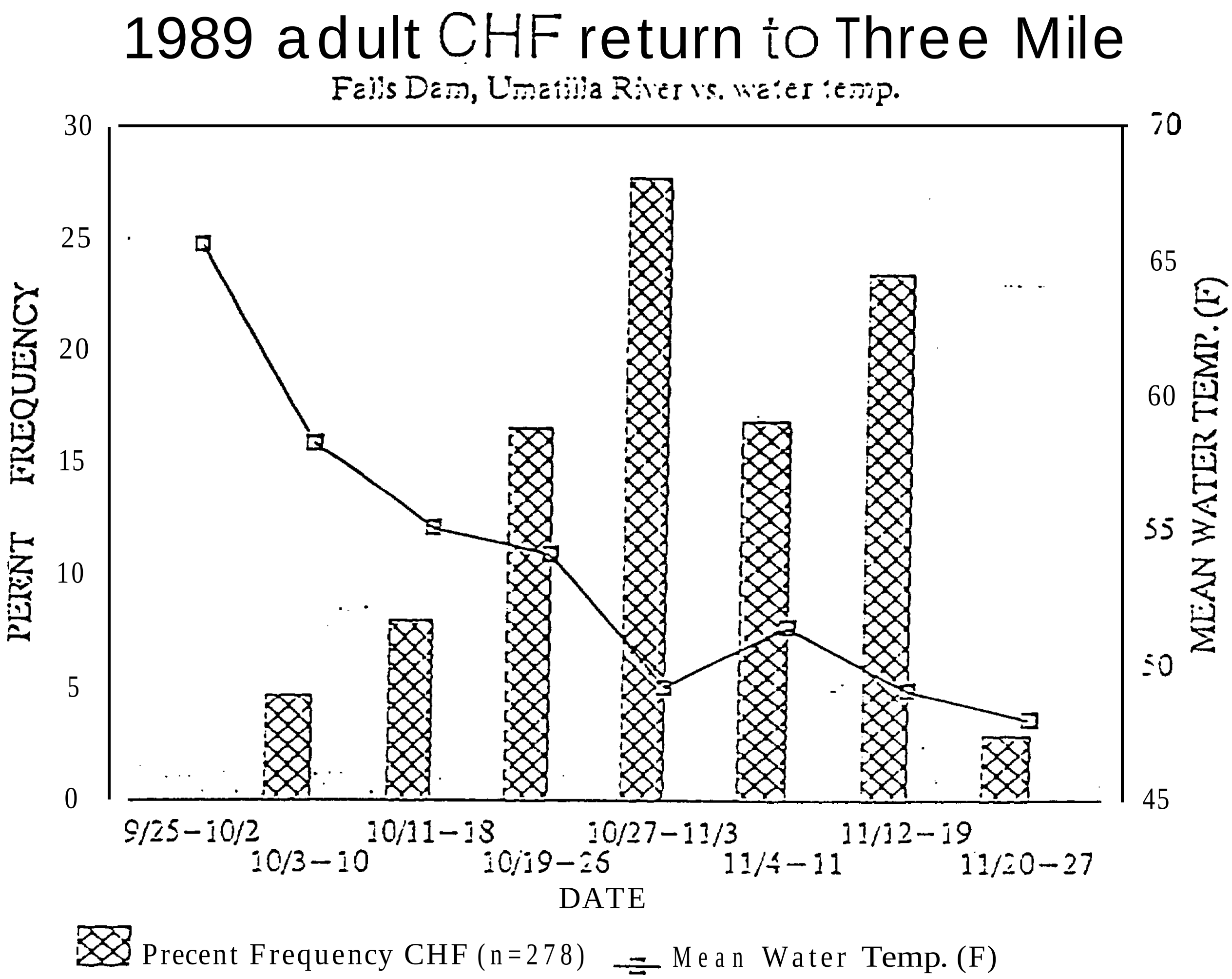
1991 adult CHF return to Three Mile
Falls Dam, Umatilla River vs. water temp.
PERCENT FREQUENCY
MEAN WATER TEMP. (F)
60
50
40
30
20
10
0
70
65
60
50
45
40
9/17-24
9/25 10/2
10/3-10
10/11-18
10/19-26
10/27-11/3
11/4-11
11/12-19
11/20-27
DATE
Precent Frequency CHF (n=521)
Mean Water Temp (F)

Figure 16.



1989 adult CHF return to Three Mile
Falls Dam, Umatilla River vs. flow.
PERCENT FREQUENCY
MEAN FLOW (CFS)
30
25
20
15
10
5
0
500
250
200
150
100
50
0
9/25–10/2
10/3–10
10/11–18
10/19–26
10/27–11/3
11/4–11
11/12–19
11/20–27
DATE
Perceent Frequency CHF (n=278)
Mean Daily Flow (CFS) Umatilla Gage

Figure 17.



1989 adult CHF return to Three Mile
Falls Dam, Umatilla River vs. water temp.
PERENT FREQUENCY
MEAN WATER TEMP. (F)
30
25
20
15
10
5
0
70
65
60
55
50
45
9/25-10/2
10/3-10
10/11-18
10/19-26
10/27-11/3
11/4-11
11/12-19
11/20-27
DATE
Precent Frequency CHF (n=278)
Mean Water Temp. (F)

Table 4. Estimated fall chinook salmon recoveries from the Umatilla River and Washington fish traps, hatcheries, and spawning grounds versus attraction flows (October 1-15) in 1969 and 1996.

Return Yr.	Umatilla R.	Strays	% Stray	Avg. Flows
1969	280	282	60.2	160cfs
1990	221	103	31.6	69 cfs

Although Kissner (1993) found Umatilla River coho salmon entering the mainstem Columbia River later than Umatilla River fall chinook salmon, entry at Three Mile Falls Dam in 1991 and 1992 was similar (Figures 18 and 19)

Homing and straying information for coho salmon returning to the Umatilla River indicates that some juvenile coho salmon may not be imprinting on the Umatilla River. Straying rates for the 1987-92 return years of coho salmon ranged from 0%-25.5% (Table 5). Although a few fish did return to other hatchery facilities, a large percentage of the strays returned to their rearing facility (Bonneville Complex) and thus appear to have imprinted prior to being released into the Umatilla River (Kissner 1993). Homing rates to the Umatilla River for acclimated (80.5% to 100%) versus direct (81.4% to 100%) releases of juvenile coho salmon were comparable (Table 5).

Table 5. Umatilla River homing and straying rates for acclimated and direct releases of Juvenile coho salmon (includes acclimation/evaluation experiments).

Br. Yr.	CWT Code	No. Released	Release Location	No. Strayed	No. Homed	% Stray	% Homed
67	074609	75970	Nr. Minthorn	4	53	7.0	93.0
67	074610111	157299	Minthorn	20	219	6.4	91.6
88	074614	67309	Minthorn	48	194	19.8	60.2
88	074613	59682	Nr. Minthorn	36	156	16.6	81.4
69	075535	152974	Minthorn	0	37	0.0	100.0
69	075534	449678	RM56-60	1	156	0.6	99.4
69	075533	352977	RM63-70	0	165	0.0	100.0
**88	074615	65095	Minthorn	T7	225	25.5	745

** not part of acclimation/evaluation experiment

Figure 18.

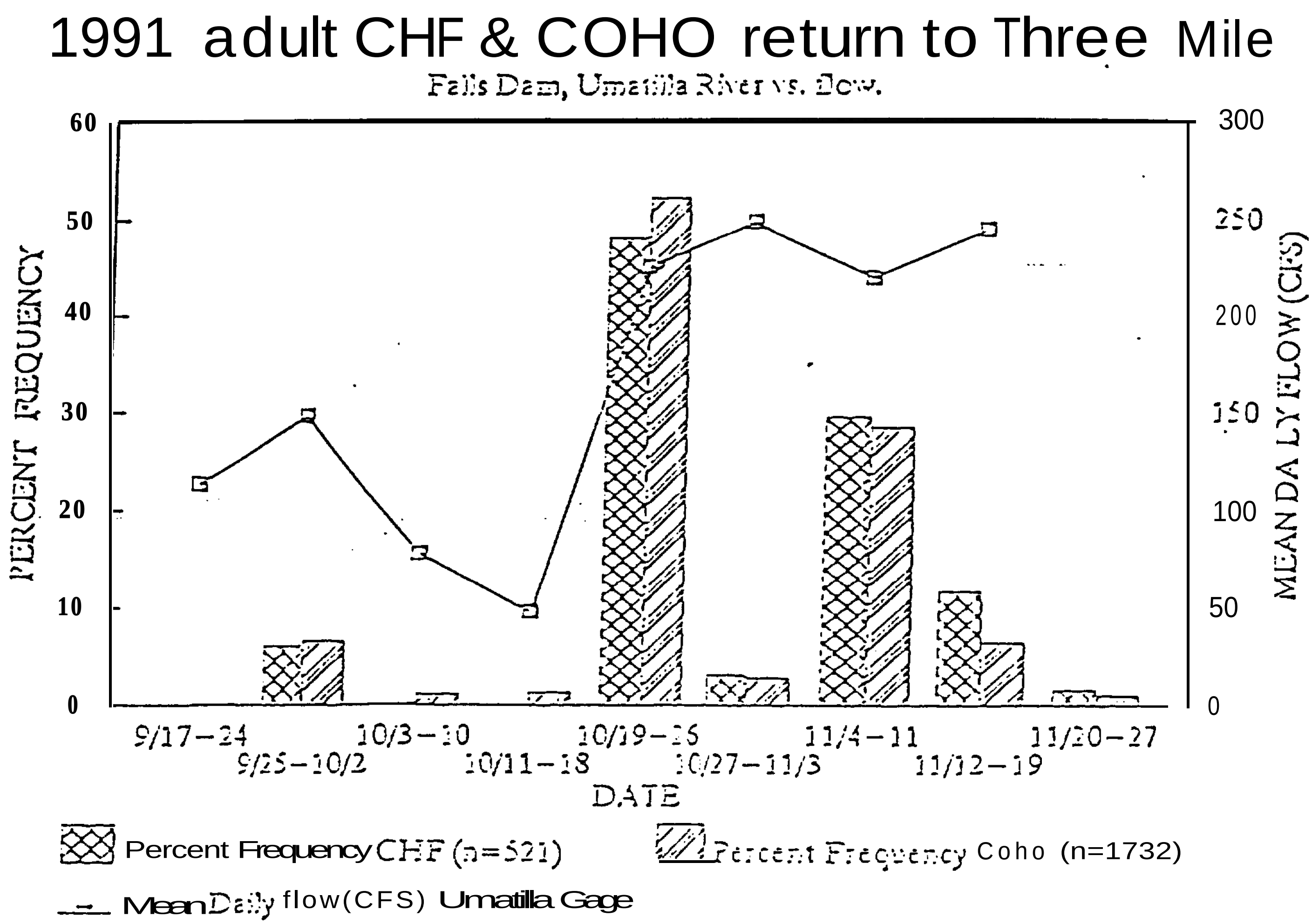
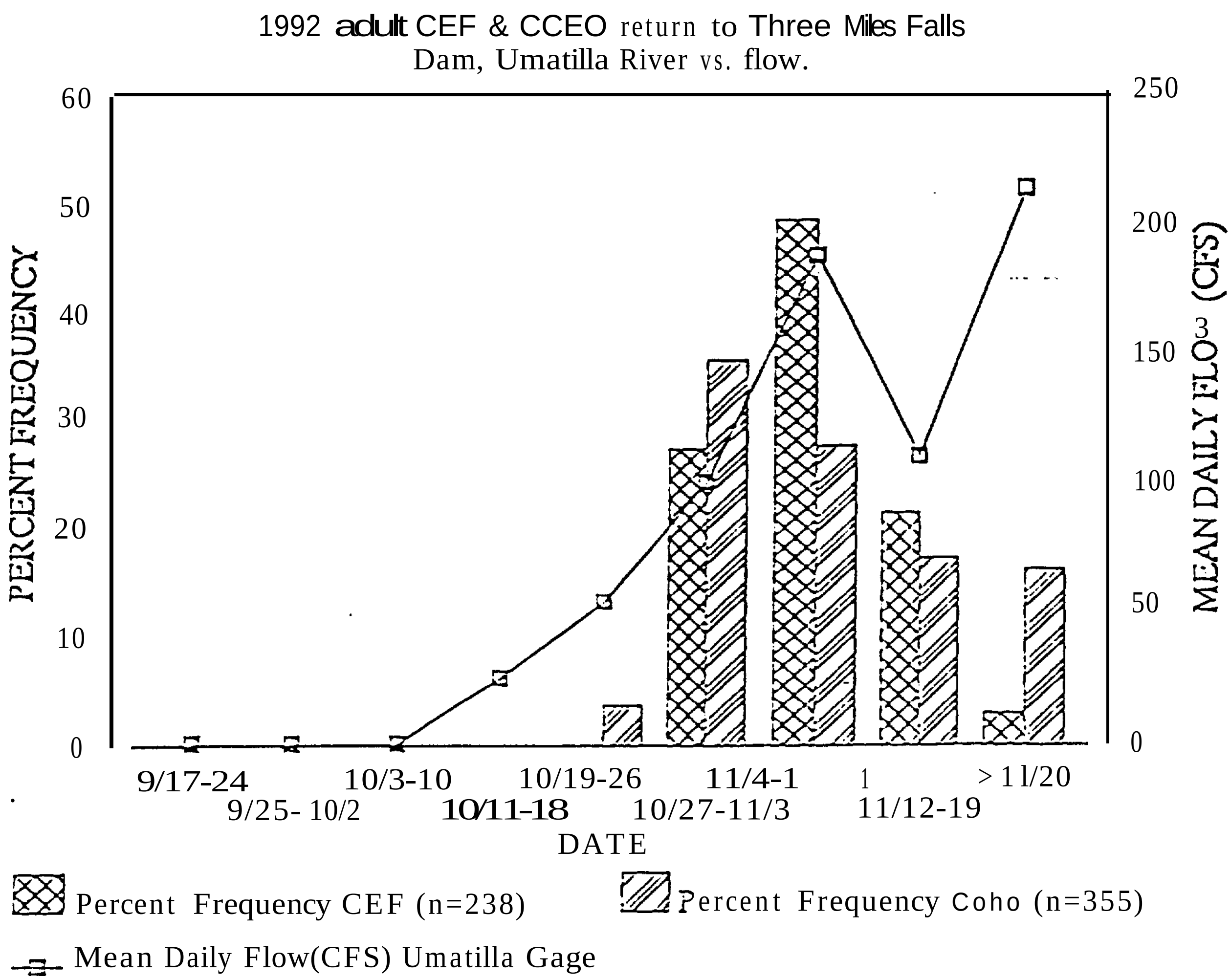

1991 adult CHF & COHO return to Three Mile
Falls Dam, Umatilla River vs. flow.
PERCENT FREQUENCY
MEAN DAILY FLOW (CFS)
60
50
40
30
20
10
0
300
250
200
150
100
50
0
9/17-24
9/25-10/2
10/3-10
10/11-18
10/19-26
10/27-11/3
11/4-11
11/12-19
11/20-27
DATE
Percent Frequency CHF (n=521)
Percent Frequency Coho (n=1732)
Mean Daily flow(CFS) Umatilla Gage

Figure 19.



1992 adult CEF & CCEO return to Three Miles Falls
Dam, Umatilla River vs. flow.
PERCENT FREQUENCY
60
50
40
30
20
10
0
MEAN DAILY FLO3 (CFS)
250
200
150
100
50
0
9/17-24
9/25- 10/2
10/3-10
10/11-18
10/19-26
10/27-11/3
11/4-1 1
11/12-19
> 11/20
DATE
Percent Frequency CEF (n=238)
Percent Frequency Coho (n=355)
Mean Daily Flow(CFS) Umatilla Gage

Despite strong Umatilla River attraction flows, spring chinook salmon telemetry data provided by the University of Idaho revealed that Umatilla River spring chinook salmon may migrate above McNary Dam prior to entering the Umatilla River. In 1993, six adult spring chinook salmon radio-tagged at John Day Dam (Columbia River), entered the Umatilla River and were recaptured at Three Mile Falls Dam. Data collected during recapture (at Three Mile Falls Dam) allowed CTUIR to receive original tagging dates and mainstem (Columbia River) migrational patterns following release. Nearly all those monitored, migrated up to and over McNary Dam prior to falling back and entering the Umatilla River (Table 6).

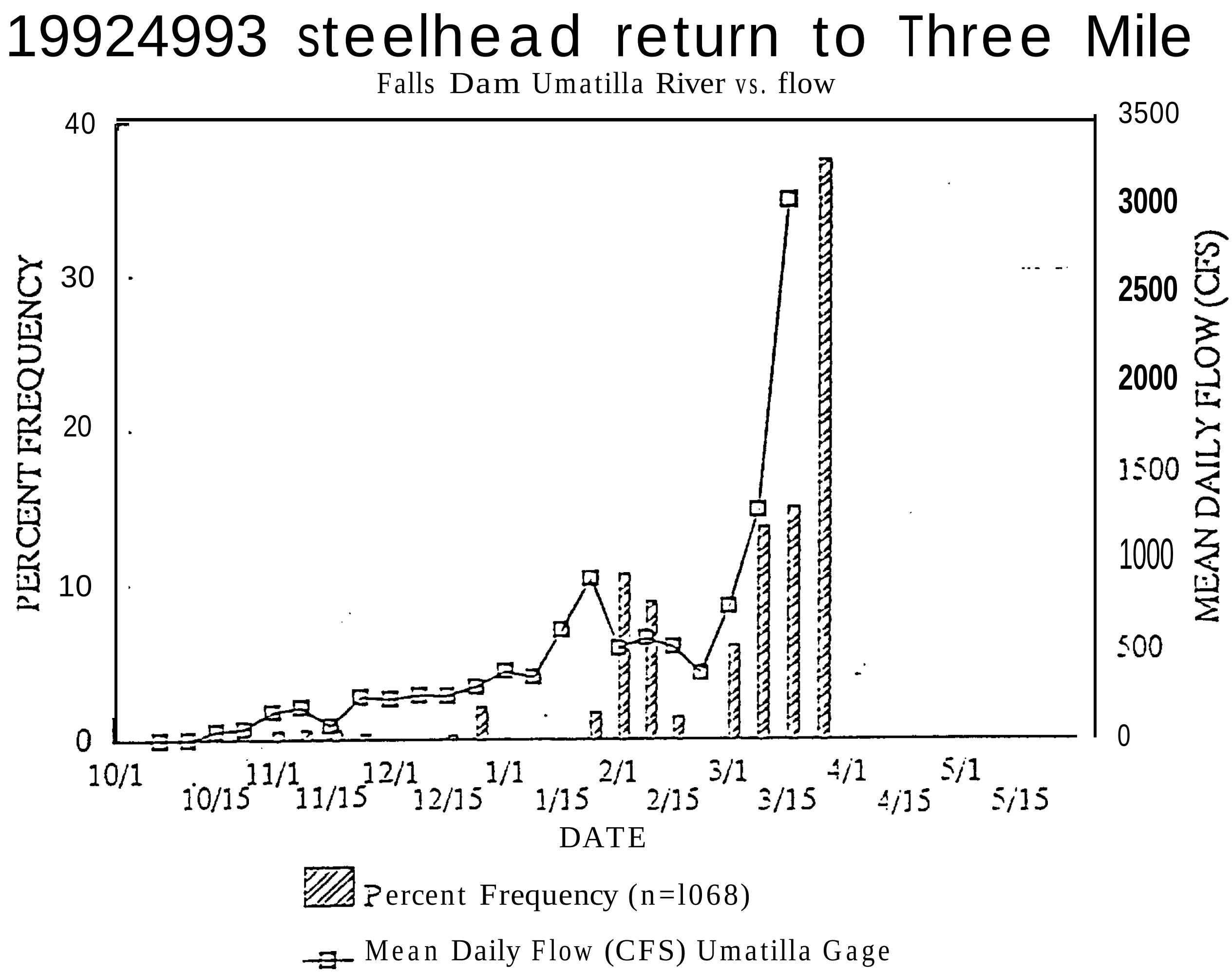
Table 6. Mainstem migrational patterns for Umatlla River spring chinooks tagged by the University of Idaho at John Day Dam (Columbia River) 1993.

Channel	Code	JDD Rel. Date	3MD Date	Days to 3MD	Mainstem Migrational Movements
12	43	4/30/93	5/12/93	12	Recorded at 2 McNary May 3, 1993 Recorded at 1 McNary May 7, 1993
5	18	4/26/93	5/14/93	18	Passes 1 McNary May 4, 1993
7	46	4/26/93	5/14/93	18	Recorded at 1 McNary May 5, 1993
6	42	5/17/93	6/8/93	22	Recorded at 1 McNary May 29, 1993 Recorded at 2 McNary June 2, 1993
7	49	5/14/93	611193	18	No Records
4	la	4/28/93	5/12/93	14	Over 2 McNary April 30, 1993 Recorded top of S. shore Ice Harbor May 3, 1993

McNary 1 = Southshore Ladder
McNary 2 = Northshore Ladder

Kissner (1992) found Umatilla River summer steelhead in the mainstem Columbia River (Zone 6) from August 1 through October 31. While straying rates for summer steelhead are generally low, entry timing into the Umatilla River varies greatly and can extend over several months (Figure 20) .

Figure 20.



19924993 steelhead return to Three Mile
Falls Dam Umatilla River vs. flow
PERCENT FREQUENCY
MEAN DAILY FLOW (CFS)
40
30
20
10
0
3500
3000
2500
2000
1500
1000
500
0
10/1
10/15
11/1
11/15
12/1
12/15
1/1
1/15
2/1
2/15
3/1
3/15
4/1
4/15
5/1
5/15
DATE
Percent Frequency (n=l068)
Mean Daily Flow (CFS) Umatilla Gage

DISCUSSION

Radio Telemetry

Because the 1992-93 adult passage evaluation was intended to be a feasibility study, a brief. discussion concerning equipment is appropriate. Pulse-code radio tags proved effective although the smaller-sized tags used for summer steelhead created more regurgitation problems. Although initial tests on the effective tracking range of the transmitters were not promising, actual field results were acceptable. Radio telemetry proved effective on the Umatilla River and will provide valuable data related to adult passage through diversion dam areas.

The delayed migration of spring chinook salmon at Feed Canal Dam appeared to be related to problems in attraction flows at the structure. As flows reduced, most of the water was spilling over the dam on the side opposite the fish ladder. Had the majority of water been directed towards the fish ladder, much of the delay may have been reduced. The apron at the base of the diversion dam does not allow fish to successfully jump over, except at very high flows. Because of this, it is imperative that attraction water be directed towards the fish ladder as flows reduce. The possibility exits that fish holding below diversion structures are simply resting or holding before proceeding upstream. Nevertheless, given adequate water temperatures,. when a fish displays continual upstream migration before and after a period of no movement at a diversion dam it is assumed to be delayed.

Tracking data collected at Feed Canal Diversion Dam for spring chinook salmon did not conclusively determine that any radio-tagged fish were unable to negotiate the structure. However, it is suspected that two fish were'stopped by the diversion. Two spring chinook salmon were unable to negotiate Feed Canal Dam and remained below the structure for a long period of time. The fish then moved and could not be found either up or downstream of the diversion dam. Both were then located approximately 80 river kilometers (50 river miles) upstream in Meacham Creek. Because the tracking data could not prove otherwise, the fish were assumed to have successfully past the diversion and migrated upstream. More likely, however, the fish fell back to Three Mile Falls Dam, were recaptured, and hauled upstream.

During the 1993 evaluation, one radio-tagged spring chinook salmon was documented in Westland Canal. The fish was released late in the migratory period (May 19, 1993) as flows in the Umatilla River were drastically reducing. The fish migrated steadily upstream until reaching Westland Dam on May 26, 1993. At this time, attraction flows exiting the old wasteway below Westland Dam exceeded those coming over the dam. As a result, the fish migrated up the wasteway and into the canal. Several other spring chinook salmon were observed within the canal (behind the drum screens) during this same time period. This situation occurs when river flows (above Westland Dam) are slightly greater than what is being diverted into Westland Canal. In an attempt to reduce stranding of downstreammigrants, CTUIR and ODFW trap and haul personnel request that all water be diverted-into the canal to allow capture of all juveniles for downstream transport. The surplus water is then returned to the river through the old wasteway. A passage barrier, or adult trap at the mouth of the wasteway is needed to remedy this situation.

Unlike spring chinook salmon,, summer steelhead tagged during the 1992-93 evaluation did not display major delays below diversion dams. One fish was delayed at Westland Diversion Dam during extremely high flows but quickly resumed migration as flows reduced. Some hesitation was also documented below Feed Canal Dam but cold water temperatures coincided with the arrival of the fish and may have influenced movement. In general, summer. steelhead appeared to be content with waiting until conditions were suitable for migration. As Kissner (1993) pointed out, unlike other salmonids returning to the Umatilla River, wild summer steelhead have survived because their life history allows a long period of time between Columbia River entry and spawning. This provides summer steelhead with the ability to wait for prolonged periods, if necessary, until adequate migrational conditions exist.

Three Mile Falls Dam West-Bank Operation

The west-bank facility fish ladder at Three Mile Falls Dam operated well and could be used successfully in a bypass mode in its current condition. However, if the trap is to be used for trapping, handling, sampling, or hauling adult salmonids, major modifications to the existing design need to be made.

The adult trap V-notch entrance does not allow the trap to be properly crowded and may permit escape of trapped adults. Also, the trap does not afford an effective way of transferring trapped adults from the trap to the fish lock hoist, and the horizontal crowder does not have an automatic stop. In addition, the entrance gates (G-l,G-2), and attraction flow gate, were very difficult and time consuming to operate. These should be automated so that operational needs of'the facility can be met more easily.

The percentage of fish captured in the west-bank facility may not be representative of the migratory potential of the facility. -A more accurate picture of salmonid movements into the west-side fish ladder should include long periods of evaluation over a large range of river flows. Because the facility was dewatered each day and had not been recently operated, fish may have felt unsafe entering and ascending the fish ladder. Given constant flows through the facility, such as those on the east-side, greater numbers of fish may have chosen the west-side fish ladder as the passage route over Three Mile Falls Dam.

Homing and Passage Needs in the Umatilla River

Homing success of Umatilla River salmonids are contingent on conditions during juvenile release and adult return. To reduce straying, fall chinook salmon should be acclimated, and released in upriver locations. It is expected that fall chinook salmon straying will be reduced in the future as a result-of increased acclimation and the Umatilla Basin flow enhancement project.

Straying rates for Umatilla River summer steelhead and spring chinook salmon are likely low because of generally stronger attraction flows and more desirable water temperatures encountered during upstream migration.

Straying rates observed for fall chinook and coho salmon are much higher. Low flows and high water temperatures encountered during the adult return in conjunction with juvenile imprinting problems are likely responsible.

Data for adult fall chinook salmon does not clearly 'demonstrate that either water temperatures or flows are directly responsible in all return years for late entry of these fish to Three Mile Falls Dam. It may be found that some fall chinook salmon naturally migrate upstream of the mouth of the Umatilla River regardless of attraction flow levels and thus induce delayed entry at Three Mile Falls Dam. This type of behavior was clearly documented (discussed earlier) with radio telemetry during 1993 for spring chinook salmon at attraction flows far exceeding those experienced during the fall chinook salmon migration. Fall chinook salmon migrating above McNary Dam may simply be "testing" for Umatilla River water with the intention of dropping back if the Umatilla River is not detected. Once over the dam however, they find passage back through the dam difficult and thus spend days if not weeks in the McNary pool and forebay before successfully falling back and entering the Umatilla River. A delay such as this would not be a problem for summer steelhead or spring chinook salmon because of the long duration between Umatilla River entry and spawning. For fall chinook salmon, however, a small delay would be crucial in the ability of these fish to enter the Umatilla River on an acceptable date and successfully migrate to suitable spawning sites.

Determination of the delaying factor, either water temperatures, attraction flows, or mainstem migrational patterns, is difficult. Typically, as flows increase, temperatures decrease, making the determination of delay (either temperatures or flows) impossible. Several combinations of conditions at various flows and temperatures would provide needed information. This information along with data regarding mainstem migrational movements of Umatilla River fall chinook salmon at various attraction flows will better enable determination of delay.

Recommendations:

Passage problems were identified during the 1992-93 evaluation at both Westland and Feed Canal diversion dams. Recommendations are as follows.

1. Install an adult passage barrier at or near the mouth of the wasteway below Westland Dam. This will effectively eliminate movements of adult salmonids into the canal during low river-flow conditions.

2. Attraction flows at Feed Canal Dam should be directed towards the fish ladder. This becomes increasingly important during low river-flow conditions and may involved in-streamwork both above and below the diversion dam. Greater attraction flows towards the fish ladder, will better enable migrating adult salmonids to successfully negotiate Feed Canal Dam.

Plans for the 1993-94 Adult Passage Evaluation

CTUIR will conduct an expanded version of the 1992-93 adult passage evaluation for the 1993-94 study. The study will include the use of fixed-site receivers, increase the number of radio tags used per species, and evaluate the movements of salmonids following upstream transport.

Intensive stream surveys during the past three years on the Umatilla River have documented only 30-50% of the spring chinook salmon escapement released above Three Mile Falls Dam. It appears possible that some transported adults are not successfully migrating to desirable spawning locations or are migrating back downstream and out of the Umatilla River. This behavior was documented in 1993 for three spring chinook salmon hauled above Pendleton and recaptured at Three Mile Falls Dam. Radio telemetry will. provide information needed to evaluate the success of different release strategies related to trap and haul programs and the movements of adult salmonids following upstream transport and release.

Although CTUIR conducted a small radio telemetry study on the Umatilla River in 1992-93, the migrational movements of adult salmonids in the Umatilla River are relatively unknown. Fixed site receivers at each of the laddered diversion facilities will enable CTUIR to record time of arrival and passage route chosen at various river flows (fish ladder or structure). Fixed site receivers combined with mobile tracking efforts, will provide constant surveillance of both upstream and downstream movements of radio-tagged salmonids and will allow CTUIR to more effectively determine migrational patterns in the Umatilla River.

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REPORT C

Evaluation of effects of transporting juvenile salmonids on the Umatilla River at high temperatures

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Oregon Department of Fish and Wildlife

CONTENTS

ABSTRACT

We report on our efforts in summer 1992 to determine the delayed mortality of juvenile salmonids and evaluate the response of juvenile salmonids to secondary stressors after being trapped at Westland diversion, -transported at various loading densities, and released in the lower Umatilla River. We also report on water quality parameters during transport.

Water quality during transport generally remained within acceptable levels. However, dissolved oxygen in the high density transport group was low. Total ammonia was $\leq$ 2.81 mg/l, and pH in the transport trailers ranged from 6.9 to 7.3. Dissolved oxygen concentration ranged from 9.8 mg/l to 12.8 mg/l in the low-density transport groups, but was only 5.4 mg/l in the high-density transport group.

Wound rate varied, but delayed mortality of chinook salmon held for 48 hours was minimal after transport. Average wound rate of live fish (95% confidence limit for percents) was 0.16% (0.06-0.74) for the control groups, 0.07% (0.03-0.41) for the high-density transport groups, and 1.25% (0.58-2.41) for the low-density transport groups. Average mortality (95% confidence limit for percents) was 0% (0) for control groups, 0.32% (0.15-0.79) for high-density transport groups, and 0.77% (0.30-1.72) for low-density transport groups.

Response of fish to 26 ppt secondary salt water challenge varied between treatments and control. After 24 hours in 26 ppt salt water, control group mortality (95% confidence limit for percents) was 6.81% (1.48-18.59), low-density transport mortality was 68.18% (62.52-81.26), and high-density transport group mortality was 34.78% (21.42-50.91).

The data indicate that under the conditions encountered during this study, transport density has no effect on mortality in the short-term or response to a secondary salt water challenge. Apparently, the loading process is the primary stress factor. Although transport density can be maintained at the current level, it may be beneficial to determine ways of minimizing stress during the crowding and loading process.

INTRODUCTION

Historical runs of salmonids on the Umatilla River have been reduced or eliminated by a variety of factors. Currently, the Oregon Department of Fish and Wildlife (ODFW) and the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) are attempting to reestablish anadromous salmonid runs in the Umatilla River.

In 1992, over 4 million juvenile salmonids were scheduled for release in the upper Umatilla River. These fish represent a substantial investment of time, effort, and funds. As they migrate downstream, many of these fish must be collected at the Westland irrigation bypass system and transported to the mouth of the Umatilla River to avoid low flows and dewatered sections of the river. The stress and water quality these fish are subjected to during collection and transport may reduce the effectiveness of the entire restoration program through direct mortality or indirect fish loss to secondary stress or predation.

In 1990 and 1991, fish were transported from as early as April to as late as August. Many of these fish were transported at very high temperatures. Maximum daily average temperatures at Three Mile Falls Dam in 1990 during the potential transport period ranged from 12.8 C (55 F) in March to 24 C (75.2 F) in July. During the same period in 1991, maximum daily average temperatures at Three Mile Falls Dam ranged from 11.2 C (52.2 F) in March to 25.2 C (77.3 F) in July. In 1991 maximum temperatures during actual transport ranged from 21.7 C (71 F) in June to 22.8 C'(73 F) in July. We are unaware of any studies evaluating the effect of transport at these high temperatures on salmonids, although recommended transport densities at these temperatures are extremely low (Smith 1978). In fact, using the Smith (1978) formula, no salmonids should be transported at these temperatures.

There is extensive literature dealing with the effects of transport on salmonids. Much literature indicates that handling is a primary stressor, and fish may recover during transport, but be stressed again at release (Barton et al. 1980; Maule et al. 1988). However, poor water quality during transport may inhibit recovery or cause additional stress (Specker and Schreck 1980). High temperatures impact water quality through elevating metabolic rate of fish, which increases waste production and lowers oxygen levels.

Minimizing stress during the handling and loading process is difficult. Wagner (1990) found no difference among various loading techniques on stress indicators of catchable rainbow trout. Walters et al. (1991) data for rainbow trout and fall chinook salmon also indicate no differences among several loading techniques on injury or direct mortality rate.

Many techniques have been evaluated to minimize stress and mortality during transport. Some techniques not currently used during transport on the Umatilla River include temperature control (Phillips and Brockway 1954; Horton 1956), anesthesia (Bezdek 1957; Strange and Schreck 1978; Wedemeyer et al. 1985), and isotonic transport media (Collins and Hulsey 1963; Wedemeyer 1972; Redding and Schreck 1983). In addition, limits on transport density have been proposed (Smith 1978). All of these techniques have met with varying success. Of all these options, control of transport density appears to be the least expensive and easiest to implement under the conditions of transport on the Umatilla River.

METHODS

To determine the impact of salmonid transport on direct mortality and susceptibility to secondary stress, we evaluated the effect of hauling subyearling chinook salmon from the Westland collection facility to the mouth of the Umatilla River. We incorporated two replicate non-transported groups as controls, two replicate high-density transport groups at 0.084 kg/l and 0.081 kg/l, and two replicate low-density transport groups at 0.029 kg/l and 0.026 kg/l. Transport was conducted in as short a time frame as possible on 20 May 1992. We selected this time period since data indicated that subyearling chinook salmon dominated the transport groups during these dates, and enough fish were available to conduct valid tests. Chinook salmon were selected as the primary study animals since they appear to be more sensitive to transport stress than many other salmonids (Wedemeyer et al. 1985). Therefore, they should be a good indicator species for detrimental effects of transport on the Umatilla River.

We conducted the transport evaluation in a manner minimizing interference with transport operations and other research projects. Prior to transport, we placed two replicate control groups of fish in net pens at the Westland collection facility, and placed subsamples of 20 fish in 26 ppt salt water. Data collection was as noted below for the experimental groups.

Two replicate groups from each transport density were collected using a crowder, loaded on two 370-gallon (1,400 1) tank trailers with a Nielsen fish pump, and hauled for 65 - 70 minutes to the mouth of the Umatilla River. Each trailer transported a high-density group for one replicate, and a low-density group for another replicate. For both replicates, the high-density group was loaded on the tank trailer first. As fish were flushed out of the tank through the release pipe, a portion were diverted into a net pen. This was done to minimize additional handling, but the process limited control over actual numbers of fish held. We placed a subsample of 20 fish from each of the replicates in 26 ppt salt water, with an additional subsample of 20 fish placed in fresh water. Fish held in salt water and fresh water were subjected to ambient river temperatures using a water bath, with aeration provided through oxygen addition. After 24 hours, we enumerated wound rate and live and dead or moribund fish. Wound criteria included head or eye damage, lacerations, subcutaneous bleeding, deep bruises, internal bleeding as defined by bleeding at the anus, split or bleeding fins, and descaling greater than or equal to 40% of one side.

Fish not subsampled remained in the net pens for 48 hours. We then determined the wound rate and number of live and dead or moribund fish. We determined dissolved oxygen, temperature, pH, and total ammonia in the transport tanks prior to transport and at release.

We compared lengths of fish from each treatment subjected to salt water challenge using analysis of variance. We compared mortality rates and wound rates using a Chi-square contingency table. If a significant difference was noted, we did multiple comparisons using a binomial test and adjusted the alpha level using the Dunn-Sidak method (see Sokal and Rohlf 1981).

RESULTS AND DISCUSSION

Water quality during transport generally remained within acceptable levels. However, dissolved oxygen in the high-density transport group was low (Table 1). In the two low-density transport groups, (1) total ammonia at release was 0.95 mg/l and 1.10 mg/l, (2) pH at release was 7.2 and 7.3, (3) water temperature at release for both replicates was 14.0 C, and (4) dissolved oxygen concentration was 12.8 mg/l and 9.8 mg/l (Table 1). We did not collect all water quality information for both high-density transport groups, but available data are as follows: (1) total ammonia was 2.81 mg/l, (2) pH at release was 6.9, (3) water temperatures were 14.0 C and 14.3 C, and (4) dissolved oxygen concentration was 5.4 mg/l (Table 1).

Ammonia levels during the current experiment were similar to that encountered by Specker and Schreck (1980) during low-density (0.012 kg/l) transport of coho salmon. Specker and Schreck (1980) noted ammonia levels during 4 - 12 hour transport of coho salmon at 0.012 kg/l ranging from 2.0 mg/l to 3.4 mg/l. However, dissolved oxygen in the high-density transport group during the current experiment was substantially lower than that noted by Specker and Schreck (1980) during transport at 0.012 kg/l and 0.12 kg/l, where oxygen remained near saturation.

Response of fish to 26 ppt secondary salt water challenge varied between treatments and control. After 24 hours in 26 ppt salt water, control group mortality (95% confidence limit for percentages) was 6.81% (1.48-18.59), low-density transport mortality was 68.18% (52.52-81.26), and high-density transport group mortality was 34.78% (21.42-50.91; Table 2). Mortality rates of both treatments and the control group were all significantly different at the 0.05 level (critical alpha adjusted to $P < 0.017$ for multiple comparisons using the Dunn-Sidak method; Table 2). The results of the current study support those of previous studies indicating that loading fish has been identified as the primary stressor in transport operations (Barton et al. 1980; Specker and Schreck 1980; Maule et al. 1988). The low-density transport replicates were both loaded after the high-density transport groups, and were therefore exposed to additional loading stress through repeated crowding and a longer time period under crowded conditions. This may explain the higher mortality under secondary salt water stress.

Wound rate of fish transported and then held for 48 hours varied between the treatments. Average percentage of wounded fish (95% confidence limit for percentages) of live chinook salmon was 0.16% (0.06-0.74) for the control groups, 0.07% (0.03-0.41) for the high-density transport groups, and 1.25% (0.58-2.41) for the low-density transport groups (Table 3). The wound rate of the low-density transport group was significantly different from both the high-density and control wound rates ($P < 0.05$, critical alpha adjusted to $P < 0.017$ using the Dunn-Sidak method for multiple comparisons), but there was no significant difference between the control group and high-density transport group (Table 3). These results indicate again that the loading process was the primary factor causing stress or injury to fish. The low-density transport groups were subjected to crowding twice and spent more time concentrated by the crowder. This subjected them to additional opportunity for mechanical injury and stress.

Table 1. Water quality of collection facilities, transport units, holding facilities, and release sites for juvenile salmonids transported at different densities from Westland Canal to the mouth of the Umatilla River, May 1992.

Location	Date	Time	Temp C	PH	Total ammonia (mg/l)	Dissolved oxygen (mg/l)
Westland Pond [a]	05/20	1040		--	0.24	8.5
Westland Canal	05/20	1040	14.0	8.6	0.33	11.5
High-Density Replicate 1	05/20	0910	14.3	6.9	2.81	5.4
High-Density Replicate 2	05/20	1200	--	--	--	--
Low-Density Replicate 1	05/20	0935	14.0	7.3	0.95	12.75
Low-Density Replicate 2	05/20	1205	14.0	7.2	1.10	9.8
Umatilla Mouth	05/20	0930	16.0	8.6	0.26	10.8
Umatilla Mouth	05/21	1000	16.0	--	--	--
Fresh water 24 h Replicate 1	05/21	--	--	--	1.64	--
Fresh water 24 h Replicate 2	05/21	--	--	--	1.43	--
Salt water 24 h Replicate 1	05/21	--	--	--	1.86	--
Salt water 24 h Replicate 2	05/21	--	--	--	2.24	--
Salt water Control	05/21	--	--	--	1.47	--

a Juvenile holding pond at Westland Canal.

Table 2. Sample size, average length, and percent dead or moribund juvenile chinook salmon held in fresh water and 26 ppt salt water for 24 hours after transport at different densities. Values within the fresh water and salt water groups followed by different letters are significantly different from each other. N - number of fish, SE = standard error of fish length.

	Fresh water				26 ppt Salt water			
Treatment	N	Percent mortality	Average length (mm)	SE	N	Percent mortality	Average length (mm)	SE
Control		0			22			
Rep 1	15	0	87.3	1.41	22	4.55	85.6	1.27
Rep 2	15		90.0	1.53		9.09	85.9	1.14
High-Density	22				23			
Rep 1	26	0	86.1	1.21	23	34.78	83.7	1.66
Rep 2		0	88.4	1.12		34.78	86.3	1.85
Low-Density	10				19			
Rep 1	26	0	86.6	2.35	25	73.68	82.1	1.49
Rep 2		0	87.5	1.49		64.00	87.6	2.00

Pooled Values

	Fresh water		26 ppt Salt water	
Treatment	Average length (mm)	Percent mortality	Average length (mm)	Percent mortality
Control	88.7^{a}	0	85.8^{a}	6.81^{a}
High-Density	87.3^{a}	0	85.0^{a}	34.78^{b}
Low-Density	87.1^{a}	0	84.9^{a}	68.18^{c}

Table 3. Percent of juvenile salmonids wounded after being transported at different densities and held for 48 hours in net pens. Values followed by different letters are significantly different from each other. N = number of fish, 95% CL = 95% confidence limits for percentages.

	Live fish					
	Steelhead			Chinook		
Treatment	N	Number wounded	Percent wounded	N	Number wounded	Percent wounded
Control	1				1	
Replicate 1	6	0	0.00	302	0	0.33
Replicate 2		0	0.00	324		0.00
High-Density	17					
Replicate 1	33	0	0.00	315	0	0.00
Replicate 2		1	3.03	1,199	1	0.08
Low-Density						
Replicate 1	16	0	0.00	127	7	5.51
Replicate 2	16	1	6.25	512	1	0.20

	Pooled data for chinook					
	Live			Dead		
Treatment	N	Percent wounded	95% CL	N	Percent wounded	95% CL
Control	626	0.16[a]	0.06-0.74	0	--	--
High-Density	1,514	0.07[a]	0.03-0.41	5	0.00	0.00-45.07
Low-Density	639	1.25[b]	0.58-2.41	5	20.00	0.51-71.60

Mortality of chinook salmon held for 48 hours was minimal after transport. Average mortality (95% confidence limit for percentages) was 0% (0.00-0.48) for control groups, 0.77% (0.30-1.72) for low-density transport groups, and 0.32% (0.15-0.79) for high-density transport groups (Table 4). There was no significant difference among any treatments ($P > 0.05$).

The results of the current study indicate that loading and'transport practices cause little or no delayed mortality, but transported fish appear to be under stress. Most of this stress appears to be caused by the crowding and loading process, since the highest mortality under secondary salt water challenge occurred in the low-density transport groups (Table 2). These low-density transport groups were crowded with the high-density groups, but loaded onto the transport trailers last. To limit mortality and stress during transport, we should concentrate on minimizing injury and stress during the crowding and loading process.

Table 4. Mortality rate of juvenile salmonids transported at different densities and held for 48 hours in net pens. Values followed by different letters are significantly different from each other. 95% CL = 95% confidence limits for percentages.

	Steelhead			Chinook		
Treatment	Live	Dead	Percent mortality	Live	Dead	Percent mortality
Control						
Replicate 1	1	0	0	302	0	0
Replicate 2	6	0	0	324	0	0
High-Density						
Replicate 1	7	1	14.3	315	4	1.27
Replicate 2	33	0	0	1,199	1	0.08
Low-Density						
Replicate 1	16	0	0	127	1	0.79
Replicate 2	16	0	0	512	4	0.78

	Pooled data for chinook		
Treatment	Percent mortality	N	95% CL
Control	0.00[a]	626	0.00-0.48
High-Density	0.32[a]	1,519	0.15-0.79
Low-Density	0.77[a]	644	0.30-l .72

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